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Firearm injuries in children and young people in Ontario, Canada.

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Data sharing: The data set from this study is held securely in coded form at ICES. Data-sharing agreements prohibit ICES from making the data set publicly available, but access may be granted to those who meet pre-specified criteria for confidential access, available

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at www.ices.on.ca/DAS. The full data set creation plan and underlying analytic code are available from the authors upon request, understanding that the programs may rely upon coding templates or macros that are unique to ICES.

Abbreviations: CI, confidence intervals; ED, Emergency Department

Contributors Statement: N. Saunders conceptualized and designed the study, interpreted the results, drafted the initial manuscript, revised the manuscript, and approved the final manuscript as submitted. C. Moore Hepburn, C. de Oliveira, R. Strauss, L. Fiksenbaum, P. Pageau, D. Gomez and A. Macpherson interpreted the results, revised the manuscript, and approved the final manuscript as submitted. A. Huang and Ning Liu had access to and analyzed the data, interpreted the results, revised the manuscript, and approved the final manuscript as submitted. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Keywords: Firearms, guns, injury, epidemiology, violence, suicide, trauma, pediatrics

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Abstract

Background and Objective: Despite firearms contributing to significant morbidity and mortality globally, firearm injury epidemiology is seldom described outside of the USA. We examined firearm injuries among young people in Canada, including weapon type, and intent.

Design: Population based, pooled cross-sectional study using linked health and administrative databases.

Setting: Ontario, Canada.

Participants: All children and youth from birth to 24-years, residing in Ontario from April 1, 2003 to March 31, 2018.

Exposure: Firearm injury intent and weapon type using the International Classification of Disease-10 CM Codes with Canadian enhancements. Secondary exposures were socio-demographics including age, sex, rurality and income.

Main Outcomes: Any hospital or death record of a firearm injury with counts and rates of firearm injuries described overall and stratified by weapon type and injury intent. Multivariable Poisson regression stratified by injury intent was used to calculate rate ratios of firearm injuries by weapon type.

Results: Of 5,486 children and youth with a firearm injury (annual rate: 8.8/100,000 population), 90.7% survived. Most injuries occurred in males (90.1%, 15.5/100,000 population). 62.3% (3416) of injuries were unintentional (5.5/100,000 population) of which 1.9% were deaths, whereas 26.5% (1452) were assault related (2.3/100,00 population) of which 18.7% were deaths. Self-harm accounted for 3.7% (204) of cases of which 72.0% were deaths. Across all intents, adjusted regression models showed males were at an increased risk of injury. Non-powdered

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firearms accounted for half (48.6%, 3.9/100,000 population) of all injuries. Compared to handguns, non-powdered firearms had a higher risk of causing unintentional injuries (adjusted rate ratio [aRR] 14.75 95%CI 12.01, 18.12) but not assault (aRR 0.84 95%CI 0.70, 1.00).

Conclusions: Firearm injuries are a preventable public health problem among young people in Ontario, Canada. Unintentional injuries and those caused by non-powdered firearms were most common and assault and self-injury contributed to substantial firearm-related deaths and should be a focus of prevention efforts.

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Article Summary

- Using linked health and administrative datasets, this study shows the extent of pediatric firearm injuries by weapon type and intent in Ontario, Canada.

Strengths of This Study

- This is the largest population-based study in Canada to describe the epidemiology of firearm injuries in children and youth outside of the United States.
- Beyond measuring injury intent, this study measures the weapon type that caused the injury and we have shown that non-powdered firearm injuries contribute to a substantial proportion of injuries in this population.
- Despite relatively strict legislation and access to firearms, firearm injuries, especially unintentional ones, are frequent among young people in Canada.

Limitations of This Study

- While data used have validated codes for intent and weapon type, we do not report data on perpetrators and have limited data on the circumstances surrounding the injury.

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Introduction

Firearm injuries are an important cause of morbidity and mortality among young people in high-income countries.[1,2] Firearm injuries, in particular from assault and self-harm, can be fatal and, among survivors, leave lasting repercussions.[3-7] Firearms also carry the highest rate of lethal injury in those who attempt suicide. Children and youth are particularly vulnerable to firearm injury as it is a period in their lives where they have increasing independence and access to firearms yet still immature executive functioning.[8]

The United States consistently leads with the highest rates of firearm homicide and suicide deaths among the Organization for Economic Co-operation and Development (OECD) countries, with Canada, Portugal and Ireland following next for per capita firearm homicides and Finland, Austria and France afterwards for per capita firearm suicides.[9] The majority of public health research related to pediatric firearm injuries is from the United States, where one third of households (and up to 61% in some states) own at least one firearm.[10,11] U.S. data reveals that only one third of families who own guns report storing their firearms safely[12] and that unintentional injuries represent one third of firearm injuries in American children[13], typically occurring either in or close to home.[14] In contrast, only approximately 17 to 34% of Canadian households own at least one firearm[15] and firearms are involved in 30% of homicides and 12% of suicides.[16]

Internationally recognized injury reporting standards categorize firearm injuries into one of five groups by intent: unintentional, intentional (assault), self-inflicted (suicide or attempted suicide), legal intervention (war, police shooting), and intent unknown, using validated diagnostic codes.[17-23] Firearms are also generally grouped into one of three types: handguns, rifles/long guns, and non-powdered firearms. Regulations around possession, acquisition, use, and transport

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of these weapons vary considerably by weapon type, yet all are capable of causing serious bodily harm, including death.[24]

In the United States, there is a strong inverse relationship between states with tighter firearm legislation, especially child access prevention laws, and firearm injury rates.[25,26] The same holds true in international jurisdictions where firearms are strictly regulated. In Australia and Japan, for example, non-powdered firearms (i.e., air guns or BB guns) require a licence to own and rifles and handguns are owned by a select few among whom use is tightly controlled.[27-29] In these jurisdictions, firearm injuries are now very low.[1]

The extent to which Canadian young people are affected by firearm injuries is not known and the sociocultural environment, drivers, normative behaviours around firearms and legislation are unique and important to understand for firearm injury prevention globally. Further, firearms data are often presented as deaths, rather than injuries. Without accounting for all injuries, including emergency department visits and hospitalizations, firearm injuries and their sequalae on patient, families, and communities are grossly underestimated.[5,6,30] Finally, reports seldom describe the weapon type or specify intent. Consequently, the extent of firearm injuries and contributing factors are often inferred or not explored due to a paucity of detailed firearm injury data available.

To inform firearm injury prevention strategies for youth, the full scope of firearm injuries in this population must first be defined. It is also critical that we understand the rate of firearm injuries, the types of firearms are being used on victims of firearm injuries by intent, and the resulting types of injuries. Knowledge of the patterns of injury are essential to shape policies and programs to prevent firearm injury. Our objectives were to describe the epidemiology of firearm-related injuries among young people in Ontario, Canada using data from emergency departments,

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hospitals and death records, and to compare the risk of injury by weapon type and intent. We hypothesized that unintentional injuries and those from non-powdered firearms would account for the majority of injuries.

Methods

Study Design

We conducted a population-based cross-sectional study in Ontario, Canada's largest province where hospital and outpatient physician services are funded through provincial health insurance to the province's ~14 million residents. For context, Canada does not currently have a firearms registry, though, older data suggests wide variation in household firearm ownership rates with 67 percent of households in the Yukon and Northwest Territories, 15 percent of Ontario, and about 30 percent in Atlantic Canada.[31,32] We used linked health and administrative datasets housed at ICES (formerly The Institute for Clinical Evaluative Sciences), a not-for-profit research institute whose legal status under Ontario's health information privacy law allows it to collect and analyze health data without individual consent. Datasets are linked through encoded unique health identification numbers for all persons with provincial health insurance. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines.

Data Sources

To identify individuals with firearm injuries, we used diagnostic codes from provincial portions of hospital discharge (Canadian Institutes for Health Information Discharge Abstract Database), emergency department and same-day surgery (National Ambulatory Care Reporting System), and death (Ontario Registrar General – Vital Statistics, Deaths) databases. We used Ontario's

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health care registry, the Registered Persons Database, to obtain demographic data for all Ontario residents eligible for public health insurance and Immigration, Refugees and Citizenship Canada's Permanent Resident Database for immigration information. We linked individual level postal codes to Canadian census data to obtain neighbourhood level income and to determine rural or urban residence. ICES data are widely used and valid for sociodemographic characteristics, physician billing claims and primary hospital diagnoses.[33]

Study Population

We included children and young people from birth to 24 years old living in Ontario, Canada from April 1st, 2003 to March 31st 2018 and eligible for provincial health insurance. The United Nations uses 24 years as the cut-off for defining youth and the Centre for Disease Control and Prevention (CDC) also uses up to 24 years to measure youth violence, and thus we did the same.[34,35] Here, we use the terms youth, young people, and emerging adults interchangeably.

Patient and public involvement

No patient involved.

Outcomes

The framework for measurement of firearm injury was based on the international framework for injury surveillance developed by the CDC and the World Health Organization (WHO), using the International Classification of Disease Clinical Modification 10 External Cause of Injury Codes for use in administrative data, with Canadian enhancements (ICD 10-CA).[17,36,37] The primary outcome was a firearm injury event identified through emergency department visit, hospitalization, or death certificate. Secondary outcomes were 1) the intent of the firearm injury, including: unintentional, assault, self-harm/suicide, and undetermined and 2) the weapon type:

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handgun, rifle, non-powdered firearm, and undetermined or unspecified (Appendix A, Firearm Codes). For each injury event, we measured the place of injury, nature of the injury (e.g., fracture, contusion), and type (location) of injury (e.g. traumatic brain injury, extremity, thorax) using International Classification of Diseases, 10th Revision codes. Individuals with an emergency department visit resulting in hospitalization or death were considered a single event. Death by firearm out-of-hospital was only available until December 31st, 2016, so these deaths due to injury were not captured in the last 15 months of the 15-year study period. In Canada, non-powdered firearms are considered firearms under Canada's Firearms Act only if the muzzle velocity exceeds 152.4 metres/second (m/s) and the muzzle energy surpasses 5.7 joules.[38] Nonetheless, firearms with projectile velocities of 75 m/s can penetrate eyes[39] and, depending on the mass of the bullet, can penetrate skin at 53 m/s[40] – thresholds far below those that are regulated. Further, what constitutes the legal definition of a firearm in health data varies by jurisdiction with legal definitions in the United States including only those with chemical combustion for a projectile and in Australia including non-powdered weapons without specification about muzzle velocities.[41,42]

Covariates

Covariates included age, sex, neighbourhood material deprivation quintile measured using the Ontario Marginalization Index[43], neighbourhood level income quintile, immigration status, rurality using the Rurality Index of Ontario[44], and hospital type at initial presentation (i.e., pediatric teaching, non-pediatric teaching, community hospitals).

Statistical Analyses

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Baseline characteristics of individuals injured versus killed by firearm were compared and reported as numbers and proportions. Crude and strata-specific rates of injury by weapon type, intent and socio-demographic characteristics were calculated using the corresponding Ontario population as the denominator. Multivariable Poisson regression models were used to estimate rate ratios with 95% confidence intervals [CIs] with weapon type as the primary exposure and age and sex as covariates. Separate regression models were used for each then used for injury intent.

All analyses were conducted using SAS 9.4 for Unix (SAS version 9.4, SAS Institute Inc.). Cell sizes less than 6 were not reportable because of Ontario privacy regulations.

Ethics Approval

Use of these data was authorized under Section 45 (1) of Ontario's Personal Health Information Protection Act. This does not require review by a Research Ethics Board. This study was approved by the ICES privacy office (ICES logged study: 2020 0990 246 000).

Results

Over the 15-year study period, there were 5,486 children and youth in Ontario injured or killed by firearms, with most (90.7%) of those injured surviving (Table 1). Most injuries and deaths occurred in males (90.1%) and in those between 18 and 24 years (61.5%). Individuals living in low-income neighbourhoods (i.e., quintile of 2 and below) accounted for over half (56.3%) of all firearm injuries and deaths. Similarly, neighbourhoods with high material deprivation (i.e., quintile 4 and above) accounted for over half (55.6%) of all firearm injuries and deaths. Most firearm-related injuries and deaths occurred in major urban centres (65.1%). Most injuries were

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unintentional (n = 3,416, 62.3%), and a quarter (n = 1,452, 26.5%) were from assault. Self-harm accounted for 204 (3.7%) cases, and legal intervention accounted for 61 (1.1%) cases. There were 353 (6.4%) injuries from an undetermined intent. Non-powdered firearms accounted for almost half (48.6%) of all firearm injuries and 41.7% of firearms were from an unspecified weapon type. Just over half of the total injuries presented at community hospitals (58.6%), followed by non-pediatric teaching hospitals (31.2%).

Characteristics of firearm injuries and deaths are presented in Table 2. Most injury events occurred in non-specified locations (76.4%); however, 9.2% occurred at home and 5.4% occurred on the street. Two-thirds (66.3%) of firearm injuries among survivors were open wounds, with a small proportion (12.7%) only causing superficial injuries yet still required emergency room care. One-third (33.6%) were either traumatic brain or head injuries and approximately half (44.9%) were to areas of the body with vital organs including the trunk, thorax and head (i.e., non-extremity injuries).

Males disproportionately experience firearm injuries from non-powdered firearms (6.76 per 100,000 population) and unspecified firearms (6.49 per 100,000 population) (Table 3). Adolescents between the ages of 13 and 17 years had the highest rate of firearm injury from non-powdered firearms (6.91 per 100,000 population) and emerging adults, 18 to 24 years, had the highest rate of handgun injuries (1.63 per 100,000 population). Across all weapon types, those in the lowest income quintile had the highest injury rates. Handgun and unspecified firearm type injuries occurred most in major urban areas with rifle and non-powdered firearm injury rates highest among those living in rural areas.

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For unintentional firearm injuries, highest rates were observed for non-powdered firearms and unspecified firearms, especially amongst adolescents 13 to 17 years (5.72 per 100,000 population). Males disproportionately experienced the greatest risk of unintentional-related firearm injuries from non-powdered firearms (5.39 per 100, 000 population) compared to females (0.63 per 100,000 population). Assault rates were highest from handguns (0.43 per 100,000 population) and non-powdered firearms (0.39 per 100,000 population). While assaults from handguns were most common among males and those living in urban and low-income neighbourhoods, non-powdered firearm injuries were also greatest in these groups.

Firearm injuries from self-harm occurred most often in adolescent and emerging adult males with few differences by socio-demographic characteristics. While rare relative to other intents, self-inflicted firearm injuries had the highest case-fatality rate (72.0%).

In the adjusted regression models (Table 4), individuals under 12 years of age and those aged 13-17 years were significantly less likely to be injured by a firearm than individuals aged 18 to 24 years, regardless of the injury intent. Similarly, across all models, females were less likely to be injured by a firearm compared to males. The risk of unintentional and unspecified firearm injury was higher for non-powdered firearm injury (adjusted rate ratio 1.53 [95% CI 1.42, 1.64] and 2.20 [95% CI 1.73, 2.80], respectively). The risk of unintentional firearm injury was 8.34 times higher for non-powdered firearms compared to handguns in the unadjusted model and 14.75 times higher in the adjusted model. Similar, but not as strong, results were found for unspecified firearm injury. In the adjusted model, only small differences were observed in assaults by non-powdered firearms compared to handguns.

Discussion

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In this population-based study, we found that 5,486 children and young people up to 24 years of age between 2003 and 2017 were injured or killed by a firearm in Ontario, Canada. This is equivalent to a mean of 366 firearm injuries annually and a rate of firearm injuries of 8.7 per 100,000 population. Non-powdered firearms made up the largest proportion of firearm injuries overall, whereas rifles were responsible for almost twice the number of deaths as handguns when the weapon type was identified. Almost two thirds of all injuries were unintentional and almost one quarter were from an assault. Most injuries were to boys or young men and those living in either low income or urban neighbourhoods. Almost half of all injuries were to the head, thorax, or abdomen with only a minority causing superficial injuries. Our findings highlight the magnitude and characteristics of firearm injuries among young people in Ontario, Canada and these numbers suggest firearm injuries are a serious and potentially preventable public health problem.

This study underscores the significant variation in firearm injury rates by jurisdiction. In the United States, firearm injury rates among children are reported to be between 19 to 23.5 injuries per 100,000 individuals.[30,45] Prior to this work, little data are published on children and youth outside of the United States, making other cross-jurisdictional comparisons difficult.[1,13,30,46] Similar to American studies, we found males to be at greatest risk of firearm injuries, especially as they emerge into adulthood.[13,37] Also similar to American studies, where reported, we found that most injuries occurred at home. It has been well demonstrated that injury risk from all intents is highest where there are firearms in the household. This further emphasizes the importance of adherence to safe storage practices and supports child access prevention laws designed to reduce firearm injury.[47] Like others, we demonstrate children and youth living in low-income neighbourhoods experience the highest proportion of firearm injuries.[48,49] This

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finding was observed across all weapons and intents suggesting a need to improve community safety and target such communities for firearm safety, education, and enforcement of existing legislation.[30,48]

We showed that 1.9% of unintentional and 18.7% of assault-related firearm injuries are fatal with an overall fatality rate of 9.3%. This is consistent with other reported fatality rates in young people, ranging from 2 to 12%.[45,48,50,51] The high proportion of children and youth who do not die of their injuries highlights that firearm injury surveillance must include survivors, as reporting only deaths vastly underestimates the burden of the issue.[1] Further, most of these were open wounds and to the head and torso. These 'near misses' present an opportunity for action, including potential for mandatory eye and thoracic protection while using such weapons.

Among those with self-inflicted injuries, 72.0% died, demonstrating that in this context firearms are a highly lethal injury mechanism. We have previously reported 12% of suicide deaths in Ontario youth occur by firearm.[52] Eliminating access to firearms for those experiencing mental illness or distress may help to reduce both attempted and completed suicides by firearm.[53] There were 14.7% of self-inflicted firearm injuries from non-powdered firearms with risk of injury not different from those from handguns or rifles. This suggests access to non-powdered firearms must also be considered when counselling young people with mental health concerns at risk for intentional self-injury. In the current study, rifles were involved in 28.7% of self-inflicted injuries, a proportion almost identical to that described by Hanlon et al.[54]

A high number of unintentional injuries in this study were from non-powdered firearms. Young children under 12 years have a disproportionate risk of firearm injury by non-powdered firearms (73.8% of all firearm injuries) with a still important proportion affecting adolescents (59.6%) and

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emerging adults (32%). [55] Others have shown non-powdered firearms injuries cause morbidity, especially to the eyes[39], and depending on the mass of the bullet, can penetrate skin at 53 m/s.[40] Most prior studies on non-powdered firearms have been small, single centred, or limited to pediatric hospitals only.[41,56,57] However, one US study using a nationally representative sample showed children have 13,486 visits to emergency departments annually for non-powdered firearms.[57] Regulations and legislation around possession, acquisition, use and transport of non-powdered firearms vary considerably by jurisdiction. In the US, some jurisdictions have adopted laws to address safety concerns with some states defining non-powered firearms as firearms subject to the same or similar regulations.[55,57] In Canada, lower velocity (<500 feet per second) firearms do not fall under the Canada Firearms Act, nor are they regulated by the Consumer Protection and Safety Act. There is no mandatory training, supervision, or equipment required. Given the number of injuries associated with these weapons, increased regulation of non-powdered firearms, particularly for minors, may be warranted.

Understanding factors related to firearm injuries in varying jurisdictions is important for informing strategies for prevention. While the scale of the issue may be different, there may be opportunities to learn from leading jurisdictions in terms of successful injury prevention strategies. Diversity in firearm regulations and legislation and corresponding injury rates as seen in the United States, Australia, Canada and Japan, points to a need to consider adopting firearm injury prevention approaches used in jurisdictions with low rates of injury.[25-29,58]

Strengths and Limitations

This is the largest population-based study in Canada to examine the extent of firearm injuries in young people, with specific attention to weapon type. While data used have validated codes for

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intent and weapon type, we do not report data on perpetrators and have limited data on the circumstances surrounding the injury. Many firearm injuries were of undetermined intent and weapon type, highlighting the need for better firearm injury surveillance to be able to measure if strategies to reduce injury are effective. There is wide variation in firearm ownership and weapon type across Canada and rates of injury are likely higher in regions with greater firearm ownership. Our measures likely underestimate the true burden of injury, especially for milder injuries from non-powdered firearms that may not present to a hospital.

Conclusions

We report weapon type and intent of firearm injuries among young people in Ontario. Two-thirds were unintentional and likely preventable with appropriate and enforced firearm safety standards for young people. Firearm injuries with non-powdered firearms are concerningly high and assaults and self-injury contributed to substantial firearm-related deaths and must be a focus of ongoing injury prevention efforts and surveillance for young people.

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Table 1. Baseline characteristics of children and emerging adults (0 to 24 years) who experienced a firearm injury in Ontario, Canada, 2003 to 2017. All numbers n (%) unless otherwise specified.

Variable		Firearm injury survivor	Firearm deaths	Total injuries and deaths
Overall		4,976 (90.7)	510 (9.3)	5,486
Age, years				
	0 to 12	548 (11.0)	7 (1.4)	555 (10.1)
	13 to 17	1,464 (29.4)	92 (18.0)	1,556 (28.4)
	18 to 24	2,964 (59.6)	411 (80.6)	3,375 (61.5)
	Mean ± SD	17.9 ± 4.3	20.0 ± 3.0	18.1 ± 4.2
	Median (IQR)	19 (15-21)	20 (18-22)	19 (16-21)
Sex				
	Female	509 (10.2)	36 (7.1)	545 (9.9)
	Male	4,467 (89.8)	474 (92.9)	4,941 (90.1)
Neighbourhood income quintile				
	1 (low)	1,689 (33.9)	217 (42.5)	1,906 (34.7)
	2	1,069 (21.5)	114 (22.4)	1,183 (21.6)
	3	887 (17.8)	86 (16.9)	973 (17.7)
	4	774 (15.6)	57 (11.2)	831 (15.1)
	5 (high)	*520-524	*31-35	555 (10.1)
	Missing	*33-37	*1-5	38 (0.7)
Neighbourhood material deprivation quintile				
	1 (low)	546 (11.0)	33 (6.5)	579 (10.6)
	2	683 (13.7)	64 (12.5)	747 (13.6)
	3	863 (17.3)	71 (13.9)	934 (17.0)
	4	968 (19.5)	93 (18.2)	1,061 (19.3)
	5 (high)	1,755 (35.3)	236 (46.3)	1,991 (36.3)
	Missing	161 (3.2)	13 (2.5)	174 (3.2)
Rurality				
	Major urban centre	3,174 (63.8)	395 (77.5)	3,569 (65.1)
	Urban	1,141 (22.9)	54 (10.6)	1,195 (21.8)
	Rural	505 (10.1)	45 (8.8)	550 (10.0)
	Missing	156 (3.1)	16 (3.1)	172 (3.1)
Immigrant status				
	Non-refugee immigrants	387 (7.8)	64 (12.5)	451 (8.2)
	Non-immigrants	4,380 (88.0)	418 (82.0)	4,798 (87.5)
	Refugee immigrants	209 (4.2)	28 (5.5)	237 (4.3)
Hospital type at presentation				
	Community	3,162 (63.5)	55 (10.8)	3,217 (58.6)
	Pediatric	*232-236	*1-5	237 (4.3)
	Teaching	*1578-1582	*130-134	1,712 (31.2)
	None	0 (0.0)	320 (62.7)	320 (5.8)
Firearm type				
	Handgun	343 (6.9)	-*39-43	383 (7.0)
	Rifle	269 (5.4)	69 (13.5)	338 (6.2)
	BB guns/non-powdered firearm	*2412-2416	*1-5	2,417 (44.1)
	Unspecified firearm	1,907 (38.3)	380 (74.5)	2,287 (41.7)
Injury intent				
	Unintentional	3,351 (67.3)	65 (12.7)	3,416 (62.3)
	Assault	1,180 (23.7)	272 (53.3)	1,452 (26.5)
	Self-harm	57 (1.1)	147 (28.8)	204 (3.7)
	Undetermined	347 (7.0)	6 (1.2)	353 (6.4)
	Legal intervention	41 (0.8)	20 (3.9)	61 (1.1)

*Small cell sizes (<6) have been suppressed and combined with largest group to prevent back calculation as per institutional policy.

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Table 2. Characteristics of firearm injury for children and emerging adults (0 to 24 years) in Ontario, Canada, 2003 to 2017. All numbers n (%).

	Firearm injury survivor	Firearm deaths	Total injuries and deaths
Place of injury			
Home	476 (9.6)	31 (6.1)	507 (9.2)
School	*30-34	*1-5	35 (0.6)
Athletic facility	*22-26	*1-5	27 (0.5)
Street	275 (5.5)	23 (4.5)	298 (5.4)
Trade	*133-137	*1-5	138 (2.5)
Farm	12 (0.2)	0 (0.0)	12 (0.2)
Other/not specified	4,073 (81.9)	121 (23.7)	4,194 (76.4)
Nature of injury			
Fracture	685 (13.8)	27 (5.3)	712 (13.0)
Internal organ injury	434 (8.7)	76 (14.9)	510 (9.3)
Open wound	3,300 (66.3)	215 (42.2)	3,515 (64.1)
Amputation	16 (0.3)	0 (0.0)	16 (0.3)
Blood vessel	114 (2.3)	19 (3.7)	133 (2.4)
Superficial contusion	*689-693	*1-5	694 (12.7)
Effect of foreign bodies entering orifice	72 (1.4)	0 (0.0)	72 (1.3)
Other specified	400 (8.1)	21 (4.1)	421 (7.7)
Unspecified	370 (7.4)	4 (0.8)	374 (6.8)
Type of injury			
Traumatic brain	849 (17.1)	107 (21.0)	956 (17.4)
Head (no brain)	883 (17.7)	6 (1.2)	889 (16.2)
Neck	155 (3.1)	22 (4.3)	177 (3.2)
Thorax	384 (7.7)	105 (20.6)	489 (8.9)
Vertebral column/Spine	119 (2.4)	12 (2.4)	131 (2.4)
Abdomen, lower back, pelvis	826 (16.4)	86 (16.9)	912 (16.7)
Upper extremity	1,504 (30.2)	27 (5.3)	1,531 (27.9)
Lower extremity	1,238 (24.9)	18 (3.5)	1,256 (22.9)
Multiple/system wide region	102 (2.0)	23 (4.5)	125 (2.3)
Unspecified region	*50-54	*1-5	55 (1.0)

*Small cell sizes (<6) have been suppressed and combined with largest group to prevent back calculation as per institutional policy.

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Table 3. Firearm injuries among children and emerging adults (0 to 24 years) in Ontario, Canada, 2003 to 2018 by weapon type and intent. All numbers n, (rate per 100,000 population).

	Overall	Age, years			Sex		Income Quintile		Rurality		
	total	0-12	13-17	18-24	Female	Male	Lowest	Highest	Major Urban	Urban	Rural
Overall											
Handgun	383 (0.61)	6 (0.02)	59 (0.44)	318 (1.63)	32 (0.11)	351 (1.10)	193 (1.56)	24 (0.19)	351 (0.77)	19 (0.16)	11 (0.26)
Rifle	338 (0.54)	22 (0.07)	80 (0.60)	236 (1.21)	42 (0.14)	296 (0.93)	97 (0.78)	41 (0.32)	187 (0.41)	77 (0.64)	52 (1.22)
BB gun	2,417 (3.88)	410 (1.40)	927 (6.91)	1,080 (5.53)	257 (0.85)	2,160 (6.76)	628 (5.08)	337 (2.64)	1,129 (2.49)	825 (6.90)	359 (8.44)
Unspecified	2,287 (3.67)	116 (0.39)	480 (3.58)	1,691 (8.66)	214 (0.70)	2,073 (6.49)	970 (7.85)	150 (1.17)	1,861 (4.11)	260 (2.18)	125 (2.94)
Firearm Injuries by Intent											
Unintentional											
Handgun	96 (0.15)	-	23 (0.14)	73 (0.37)	17 (0.06)	79 (0.25)	41 (0.33)	8 (0.06)	79 (0.17)	11 (0.09)	6 (0.14)
Rifle	161 (0.26)	15 (0.05)	41 (0.31)	105 (0.54)	28 (0.09)	133 (0.42)	45 (0.36)	26 (0.20)	70 (0.15)	49 (0.41)	30 (0.71)
BB gun	1,913 (3.07)	340 (1.16)	767 (5.72)	806 (4.13)	192 (0.63)	1,721 (5.39)	479 (3.88)	273 (2.14)	841 (1.86)	683 (5.71)	304 (7.15)
Unspecified	1,246 (2.00)	98 (0.33)	281 (2.10)	867 (4.44)	125 (0.41)	1,121 (3.51)	503 (4.07)	96 (0.75)	947 (2.09)	190 (1.59)	85 (2.00)
Assault											
Handgun	265 (0.43)	-	36 (0.25)	229 (1.17)	13 (0.04)	252 (0.79)	143 (1.16)	12 (0.09)	257 (0.56)	6 (0.05)	-
Rifle	94 (0.15)	-	14 (0.09)	80 (0.41)	-	94 (0.28)	36 (0.29)	-	83 (0.18)	8 (0.07)	-
BB gun	246 (0.39)	38 (0.13)	81 (0.60)	127 (0.65)	41 (0.13)	205 (0.64)	73 (0.59)	27 (0.21)	151 (0.33)	64 (0.54)	20 (0.47)
Unspecified	847 (1.3)	9 (0.03)	151 (1.13)	687 (3.52)	67 (0.22)	780 (2.44)	410 (3.32)	37 (0.29)	811 (1.78)	29 (0.24)	-
Selfharm											
Handgun	13 (0.02)	-	-	13 (0.05)	-	13 (0.04)	-	-	13 (0.02)	-	-
Rifle	59 (0.09)	-	19 (0.13)	40 (0.20)	-	59 (0.17)	12 (0.10)	8 (0.06)	26 (0.06)	15 (0.13)	13 (0.31)
BB gun	30 (0.05)	-	11 (0.05)	19 (0.10)	-	30 (0.09)	9 (0.07)	-	15 (0.03)	14 (0.11)	-
Unspecified	102 (0.16)	-	22 (0.16)	80 (0.41)	11 (0.04)	91 (0.28)	23 (0.19)	10 (0.08)	43 (0.09)	28 (0.23)	25 (0.59)
Undetermined											
Handgun	9 (0.01)	-	-	9 (0.04)	-	9 (0.03)	7 (0.06)	-	9 (0.02)	-	-
Rifle	24 (0.04)	-	13 (0.07)	11 (0.06)	-	24 (0.06)	-	-	15 (0.02)		7 (0.16)
BB gun	228 (0.37)	28 (0.10)	72 (0.54)	128 (0.66)	22 (0.07)	206 (0.64)	67 (0.54)	33 (0.26)	122 (0.27)	65 (0.54)	34 (0.80)
Unspecified	92 (0.15)	9 (0.03)	26 (0.19)	57 (0.29)	11 (0.04)	81 (0.25)	34 (0.28)	7 (0.05)	65 (0.14)	13 (0.11)	10 (0.24)

*Small cell sizes (<6) have been suppressed and combined with largest group in row to prevent back calculation as per institutional policy.
Legal intervention not included due to small cell sizes.

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Table 4. Rate ratios of firearm injuries by intent for children and emerging adults (0 to 24 years) in Ontario, Canada, 2003 to 2018.

Variable	Model 1				Model 2			
	Unintentional injuries	Assault-related injuries	Self-harm injuries	Unspecified injuries	Unintentional injuries	Assault-related injuries	Self-harm injuries	Unspecified injuries
	RR ($CI_{95\%}$)	RR ($CI_{95\%}$)	RR ($CI_{95\%}$)	RR ($CI_{95\%}$)	RR ($CI_{95\%}$)	RR ($CI_{95\%}$)	RR ($CI_{95\%}$)	RR ($CI_{95\%}$)
Weapon Type								
Handgun	0.17 (0.14-0.21)	0.51 (0.44-0.58)	0.47 (0.26-0.83)	0.56 (0.28-1.14)	0.10 (0.08-0.13)	0.34 (0.30-0.40)	0.40 (0.22-0.71)	0.39 (0.19-0.77)
Rifle	0.19 (0.16-0.22)	0.24 (0.19-0.29)	0.63 (0.45-0.87)	0.55 (0.35-0.87)	0.15 (0.13-0.75)	0.14 (0.11-0.17)	0.58 (0.42-0.80)	0.53 (0.34-0.84)
BB gun	1.42 (1.32-1.52)	0.26 (0.23-0.30)	0.39 (0.26-0.58)	1.85 (1.45-2.36)	1.53 (1.42-1.64)	0.29 (0.25-0.33)	0.41 (0.26-0.61)	2.20 (1.73-2.81)
Unspecified (ref)	1.00	---	---	---	--	--	--	--
Age								
0-12					0.18 (0.16-0.20)	0.08 (0.06-0.11)	0.34 (0.14-0.87)	0.21 (0.15-0.29)
13-17					0.88 (0.82-0.95)	0.39 (0.34-0.44)	0.83 (0.61-1.15)	0.89 (0.71-1.13)
18-24 (ref)					1.00	--	--	--
Sex								
Female					0.14 (0.12-0.15)	0.14 (0.11-0.17)	0.37 (0.22-0.60)	0.39 (0.28-0.54)
Male (ref)					1.00	--	--	--
Contrasts								
Rifles vs Handgun	1.12 (0.87-1.45)	0.47 (0.37-0.59)	1.34 (0.74-2.44)	0.98 (0.46-2.12)	1.43 (1.11-1.84)	0.40 (0.32-0.50)	1.47 (0.80-2.68)	1.38 (0.64-2.97)
BB guns vs Handgun	8.34 (6.79-10.23)	0.52 (0.44-0.62)	0.83 (0.43-1.58)	3.29 (1.69-6.41)	14.75 (12.01-18.12)	0.84 (0.70-1.00)	1.01 (0.52-1.95)	5.68 (2.90-11.11)
Unspecified vs Handgun	5.88 (4.78-7.24)	1.98 (1.72-2.27)	2.14 (1.20-3.81)	1.78 (0.90-3.53)	9.65 (7.84-11.88)	2.90(2.53-3.33)	2.52 (1.41-4.50)	2.58 (1.30-5.13)

Note. CI = confidence interval; Ref = reference category; RR = rate ratio; Model 1 includes firearm type only. Model 2 adds in covariates (i.e., age and sex).

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APPENDIX

FIREARM INJURIES

W32: Handgun discharge
W33: Rifle, shotgun and larger firearm discharge
W3400: Discharge from BB gun
W3401: Discharge from air gun
W3408: Discharge from other specified firearms
W3409: Discharge from unspecified firearm

X93: Assault by handgun discharge
X94: Assault by rifle, shotgun & larger firearm discharge
X9500: Assault by BB gun discharge
X9501: Assault by air gun discharge
X9508: Assault by other specified firearm discharge
X9509: Assault by unspecified firearm discharge

X72: Intentional self-harm by handgun discharge
X73: Intentional self-harm by rifle, shotgun & larger firearm discharge
X7400: Intentional self-harm BB gun discharge
X7401: Intentional self-harm air gun discharge
X7408: Intentional self-harm other specified firearm discharge
X7409: Intentional self-harm by unspecified firearm discharge

Y22: Handgun discharge undetermined intent
Y23: Rifle shotgun & larger firearm discharge undetermined intent
Y2400: BB gun discharge, undetermined intent
Y2401: Air gun discharge, undetermined intent
Y2408: Other specified firearm discharge, undetermined intent
Y2409: Unspecified firearm discharge, undetermined intent

Y35.0 - Legal intervention involving firearm discharge

INTENT

Unintentional Firearm Injury (ORGD only use the first 3 digits W32, W33, W34)
W32: Handgun discharge
W33: Rifle, shotgun and larger firearm discharge
W3400: Discharge from BB gun
W3401: Discharge from air gun
W3408: Discharge from other specified firearms
W3409: Discharge from unspecified firearm

Assault from firearm (intentional), ORGD only use the first 3 digits X93, X94, X95
X93: Assault by handgun discharge
X94: Assault by rifle, shotgun & larger firearm discharge
X9500: Assault by BB gun discharge
X9501: Assault by air gun discharge

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X9508: Assault by other specified firearm discharge
X9509: Assault by unspecified firearm discharge

Self-harm from firearm (suicide) ORGD only use the first 3 digits X72, X73, X74
X72: Intentional self-harm by handgun discharge
X73: Intentional self-harm by rifle, shotgun & larger firearm discharge
X7400: Intentional self-harm BB gun discharge
X7401: Intentional self-harm air gun discharge
X7408: Intentional self-harm other specified firearm discharge
X7409: Intentional self-harm by unspecified firearm discharge

Intent unknown (undetermined) ORGD only use the first 3 digits Y22, Y23, Y24
Y22: Handgun discharge undetermined intent
Y23: Rifle shotgun & larger firearm discharge undetermined intent
Y2400: BB gun discharge, undetermined intent
Y2401: Air gun discharge, undetermined intent
Y2408: Other specified firearm discharge, undetermined intent
Y2409: Unspecified firearm discharge, undetermined intent

Legal Interventions
Y35.0 - Legal intervention involving firearm discharge

If there were multiple intents in one injury episode, the following rules were used to decide the intent
Assault*intent unknown = assault
Assault*legal intervention = assault
Self-harm*intent unknown = self-harm
Unintentional*assault = assault
Unintentional*assault*legal intervention = assault
Unintentional*intent unknown = unintentional
Unintentional*legal intervention = unintentional
Unintentional*self-harm = self-harm.

WEAPON TYPE
Handgun
W32: Handgun discharge
X93: Assault by handgun discharge
X72: Intentional self-harm by handgun discharge
Y22: Handgun discharge undetermined intent

Rifle
W33: Rifle, shotgun and larger firearm discharge
X94: Assault by rifle, shotgun & larger firearm discharge
X73: Intentional self-harm by rifle, shotgun & larger firearm discharge
Y23: Rifle shotgun & larger firearm discharge undetermined intent

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BB Guns and Airgun
W3400: Discharge from BB gun
W3401: Discharge from air gun
X9500: Assault by BB gun discharge
X9501: Assault by air gun discharge
X7400: Intentional self-harm BB gun discharge
X7401: Intentional self-harm air gun discharge
Y2400: BB gun discharge, undetermined intent
Y2401: Air gun discharge, undetermined intent

Other and Unspecified
W3408: Discharge from other specified firearms
W3409: Discharge from unspecified firearm
X9508: Assault by other specified firearm discharge
X9509: Assault by unspecified firearm discharge
X7408: Intentional self-harm other specified firearm discharge
X7409: Intentional self-harm by unspecified firearm discharge
Y2408: Other specified firearm discharge, undetermined intent
Y2409: Unspecified firearm discharge, undetermined intent

Multiple weapons, the following rules apply:
BB*other = BB
Handgun*BB = First use hospitalization record, then use handgun
Handgun*other = Handgun
Handgun*rifle = First use hospitalization and then use handgun
Rifle*BB and Rifle*other = Rifle.

PLACE OF INJURY OCCURRENCE

Home or residential institution: U980, U981
School, other institution/public area: U982, U9820, U9828
Athletic areas: U983
Street/highway: U984
Trade/service/industrial/construction area: U985, U986
Farm: U987
Other/unspecified: U988, U989

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The RECORD statement – checklist of items, extended from the STROBE statement, that should be reported in observational studies using routinely collected health data.

	Item No.	STROBE items	Location in manuscript where items are reported	RECORD items	Location in manuscript where items are reported
Title and abstract					
	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 1, 4	RECORD 1.1: The type of data used should be specified in the title or abstract. When possible, the name of the databases used should be included. RECORD 1.2: If applicable, the geographic region and timeframe within which the study took place should be reported in the title or abstract. RECORD 1.3: If linkage between databases was conducted for the study, this should be clearly stated in the title or abstract.	Page 4
Introduction					
Background rationale	2	Explain the scientific background and rationale for the investigation being reported	Page 5		
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 6		
Methods					
Study Design	4	Present key elements of study design early in the paper	Page 7		
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 7		

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Participants	6	*(a) Cohort study* - Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study* - Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study* - Give the eligibility criteria, and the sources and methods of selection of participants *(b) Cohort study* - For matched studies, give matching criteria and number of exposed and unexposed *Case-control study* - For matched studies, give matching criteria and the number of controls per case	Page 8	RECORD 6.1: The methods of study population selection (such as codes or algorithms used to identify subjects) should be listed in detail. If this is not possible, an explanation should be provided. RECORD 6.2: Any validation studies of the codes or algorithms used to select the population should be referenced. If validation was conducted for this study and not published elsewhere, detailed methods and results should be provided. RECORD 6.3: If the study involved linkage of databases, consider use of a flow diagram or other graphical display to demonstrate the data linkage process, including the number of individuals with linked data at each stage.	Page 8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable.	Page 8, 9	RECORD 7.1: A complete list of codes and algorithms used to classify exposures, outcomes, confounders, and effect modifiers should be provided. If these cannot be reported, an explanation should be provided.	Page 8, 9, Appendix
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Page 8, 9		

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Bias	9	Describe any efforts to address potential sources of bias	Page 9		
Study size	10	Explain how the study size was arrived at	Page 8		
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	Page 8, 9		
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) *Cohort study* - If applicable, explain how loss to follow-up was addressed *Case-control study* - If applicable, explain how matching of cases and controls was addressed *Cross-sectional study* - If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses	Page 9		
Data access and cleaning methods		..		RECORD 12.1: Authors should describe the extent to which the investigators had access to the database population used to create the study population.	Page 3

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				RECORD 12.2: Authors should provide information on the data cleaning methods used in the study.	
Linkage		..		RECORD 12.3: State whether the study included person-level, institutional-level, or other data linkage across two or more databases. The methods of linkage and methods of linkage quality evaluation should be provided.	Page 8
Results					
Participants	13	(a) Report the numbers of individuals at each stage of the study (*e.g.*, numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed) (b) Give reasons for non-participation at each stage. (c) Consider use of a flow diagram	Page 10	RECORD 13.1: Describe in detail the selection of the persons included in the study (*i.e.,* study population selection) including filtering based on data quality, data availability and linkage. The selection of included persons can be described in the text and/or by means of the study flow diagram.	Page 10
Descriptive data	14	(a) Give characteristics of study participants (*e.g.*, demographic, clinical, social) and information on exposures and potential confounders (b) Indicate the number of participants with missing data for each variable of interest (c) *Cohort study* - summarise follow-up time (*e.g.*, average and total amount)	Page 10		
Outcome data	15	*Cohort study* - Report numbers of outcome events or summary measures over time *Case-control study* - Report numbers in each exposure	Page 10		

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		category, or summary measures of exposure *Cross-sectional study* - Report numbers of outcome events or summary measures			
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Page 10, 11		
Other analyses	17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	NA		
Discussion					
Key results	18	Summarise key results with reference to study objectives	Page 11		
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Page 12	RECORD 19.1: Discuss the implications of using data that were not created or collected to answer the specific research question(s). Include discussion of misclassification bias, unmeasured confounding, missing data, and changing eligibility over time, as they pertain to the study being reported.	Page 12
Interpretation	20	Give a cautious overall interpretation of results considering objectives,	Page 11, 12		

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		limitations, multiplicity of analyses, results from similar studies, and other relevant evidence			
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 12		
Other Information					
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 2		
Accessibility of protocol, raw data, and programming code		..		RECORD 22.1: Authors should provide information on how to access any supplemental information such as the study protocol, raw data, or programming code.	Page 3

*Reference: Benchimol EI, Smeeth L, Guttmann A, Harron K, Moher D, Petersen I, Sørensen HT, von Elm E, Langan SM, the RECORD Working Committee. The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) Statement. *PLoS Medicine* 2015; in press.

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Title: Firearm injury epidemiology in children and youth in Ontario, Canada: a population-based study.

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the original source of which is ServiceOntario. The views expressed therein are those of the authors and do not necessarily reflect those of ORG or Ministry of Government Services.

Data sharing: The data set from this study is held securely in coded form at ICES. Data-sharing agreements prohibit ICES from making the data set publicly available, but access may be granted to those who meet pre-specified criteria for confidential access, available at www.ices.on.ca/DAS. The full data set creation plan and underlying analytic code are available from the authors upon request, understanding that the programs may rely upon coding templates or macros that are unique to ICES.

Abbreviations: CI, confidence intervals; ED, Emergency Department

Contributors Statement: N. Saunders conceptualized and designed the study, interpreted the results, drafted the initial manuscript, revised the manuscript, and approved the final manuscript as submitted. C. Moore Hepburn, C. de Oliveira, R. Strauss, L. Fiksenbaum, P. Pageau, D. Gomez and A. Macpherson interpreted the results, revised the manuscript, and approved the final manuscript as submitted. A. Huang and Ning Liu had access to and analyzed the data, interpreted the results, revised the manuscript, and approved the final manuscript as submitted. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Keywords: Firearms, guns, injury, epidemiology, violence, suicide, trauma, pediatrics

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Abstract

Background and Objective: Despite firearms contributing to significant morbidity and mortality globally, firearm injury epidemiology is seldom described outside of the USA. We examined firearm injuries among youth in Canada, including weapon type, and intent.

Design: Population based, pooled cross-sectional study using linked health and administrative databases.

Setting: Ontario, Canada.

Participants: All children and youth from birth to 24-years, residing in Ontario from April 1, 2003 to March 31, 2018.

Exposure: Firearm injury intent and weapon type using the International Classification of Disease-10 CM Codes with Canadian enhancements. Secondary exposures were socio-demographics including age, sex, rurality and income.

Main Outcomes: Any hospital or death record of a firearm injury with counts and rates of firearm injuries described overall and stratified by weapon type and injury intent. Multivariable Poisson regression stratified by injury intent was used to calculate rate ratios of firearm injuries by weapon type.

Results: Of 5,486 children and youth with a firearm injury (annual rate: 8.8/100,000 population), 90.7% survived. Most injuries occurred in males (90.1%, 15.5/100,000 population). 62.3% (3416) of injuries were unintentional (5.5/100,000 population) of which 1.9% were deaths, whereas 26.5% (1452) were assault related (2.3/100,00 population) of which 18.7% were deaths. Self-harm accounted for 3.7% (204) of cases of which 72.0% were deaths. Across all intents, adjusted regression models showed males were at an increased risk of injury. Non-powdered

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firearms accounted for half (48.6%, 3.9/100,000 population) of all injuries. Compared to handguns, non-powdered firearms had a higher risk of causing unintentional injuries (adjusted rate ratio [aRR] 14.75 95%CI 12.01, 18.12) but not assault (aRR 0.84 95%CI 0.70, 1.00).

Conclusions: Firearm injuries are a preventable public health problem among youth in Ontario, Canada. Unintentional injuries and those caused by non-powdered firearms were most common and assault and self-injury contributed to substantial firearm-related deaths and should be a focus of prevention efforts.

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Article Summary

- Using linked health and administrative datasets, this study shows the extent of pediatric firearm injuries by weapon type and intent in Ontario, Canada.

Strengths of This Study

- This is a large population-based study with almost complete provincial coverage of children and youth..
- Beyond measuring injury intent, this study measures the weapon type that caused the firearm injury.
- Both in and out of hospital deaths, all hospitalizations, and all emergency department visits for firearm injuries in Ontario were captured in available data.
- This study distinguishes the type and nature of injuries caused by various firearms, demonstrating the severity of injuries by weapon type and intent.

Limitations of This Study

- While data used have validated codes for intent and weapon type, we do not report data on perpetrators and have limited data on the circumstances surrounding the injury.

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Introduction

Firearm injuries are an important cause of morbidity and mortality among youth in high-income countries.[1,2] Firearm injuries, in particular from assault and self-harm, can be fatal and, among survivors, leave lasting repercussions.[3-7] Firearms also carry the highest rate of lethal injury in those who attempt suicide. Children and youth are particularly vulnerable to firearm injury. Is it is a period in their lives where they have increasing independence, immature executive functioning, and potential access to firearms.[8]

The United States consistently leads with the highest rates of firearm homicide and suicide deaths among the Organization for Economic Co-operation and Development (OECD) countries, with Canada, Portugal and Ireland following next for per capita firearm homicides and Finland, Austria and France afterwards for per capita firearm suicides.[9] The majority of public health research related to pediatric firearm injuries is from the United States, where one third of households (and up to 61% in some states) own at least one firearm.[10,11] U.S. data reveals that only one third of families who own guns report storing their firearms safely[12] and that unintentional injuries represent one third of firearm injuries in American children[13], typically occurring either in or close to home.[14] In contrast, only approximately 17 to 34% of Canadian households own at least one firearm[15] and firearms are involved in 30% of homicides and 12% of suicides.[16]

Internationally recognized injury reporting standards categorize firearm injuries into one of five groups by intent: unintentional, intentional (assault), self-inflicted (suicide or attempted suicide), legal intervention (war, police shooting), and intent unknown, using validated diagnostic codes.[17-23] Firearms are also generally grouped into one of three types: handguns, rifles/long guns, and non-powdered firearms. Regulations around possession, acquisition, use, and transport

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of these weapons vary considerably by weapon type, yet all are capable of causing serious bodily harm, including death.[24]

In the United States, there is a strong inverse relationship between states with tighter firearm legislation, especially child access prevention laws, and firearm injury rates.[25,26] The same holds true in international jurisdictions where firearms are strictly regulated. In Australia and Japan, for example, non-powdered firearms (e.g., air guns or BB guns) require a licence to own and rifles and handguns are owned by a select few among whom use is tightly controlled.[27-29] In these jurisdictions, firearm injuries are now very low.[1]

The extent to which Canadian youth are affected by firearm injuries is not known and the sociocultural environment, drivers, and normative behaviours around firearms and legislation are unique and important to understand for firearm injury prevention globally. Further, firearms data are often presented as deaths, rather than injuries. Without accounting for all injuries, including emergency department visits and hospitalizations, firearm injuries and their sequelae on patient, families, and communities are grossly underestimated.[5,6,30] Finally, reports seldom describe the weapon type or specify intent. Consequently, the extent of firearm injuries and contributing factors are often inferred or not explored due to a paucity of detailed firearm injury data available.

To inform firearm injury prevention strategies for youth, the full scope of firearm injuries in this population must first be defined. It is also critical that we understand the rate of firearm injuries, the types of firearms are being used on victims of firearm injuries by intent, and the resulting types of injuries. Knowledge of the patterns of injury are essential to shape policies and programs to prevent firearm injury. Our objectives were to describe the epidemiology of firearm-related injuries among youth in Ontario, Canada using data from emergency departments,

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hospitals and death records, and to compare the risk of injury by weapon type and intent. We hypothesized that unintentional injuries and those from non-powdered firearms would account for the majority of injuries.

Methods

Study Design

We conducted a population-based cross-sectional study in Ontario, Canada's largest province where hospital and outpatient physician services are funded through provincial health insurance to the province's ~14 million residents. For context, Canada does not currently have a firearms registry, though, older data suggests wide variation in household firearm ownership rates with 67 percent of households in the Yukon and Northwest Territories, 15 percent of Ontario, and about 30 percent in Atlantic Canada.[31,32] We used linked health and administrative datasets housed at ICES (formerly The Institute for Clinical Evaluative Sciences), a not-for-profit research institute whose legal status under Ontario's health information privacy law allows it to collect and analyze health data without individual consent. Datasets are linked through encoded unique health identification numbers for all persons with provincial health insurance. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines.

Data Sources

To identify individuals with firearm injuries, we used diagnostic codes from provincial portions of hospital discharge (Canadian Institutes for Health Information Discharge Abstract Database), emergency department and same-day surgery (National Ambulatory Care Reporting System), and death (Ontario Registrar General – Vital Statistics, Deaths) databases. We used Ontario's

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health care registry, the Registered Persons Database, to obtain demographic data for all Ontario residents eligible for public health insurance and Immigration, Refugees and Citizenship Canada's Permanent Resident Database for immigration information. We linked individual level postal codes to Canadian census data to obtain neighbourhood level income and to determine rural or urban residence. ICES data are widely used and valid for sociodemographic characteristics, physician billing claims and primary hospital diagnoses.[33] Databases included are in the Appendix.

Study Population

We included children and youth from birth to 24 years old living in Ontario, Canada from April 1st, 2003 to March 31st 2018 and eligible for provincial health insurance. The United Nations uses 24 years as the cut-off for defining youth and the Centre for Disease Control and Prevention (CDC) also uses up to 24 years to measure youth violence, and thus we did the same.[34,35]

Patient and public involvement

No patient involved.

Outcomes

The framework for measurement of firearm injury was based on the international framework for injury surveillance developed by the CDC and the World Health Organization (WHO), using the International Classification of Disease Clinical Modification 10 External Cause of Injury Codes for use in administrative data, with Canadian enhancements (ICD 10-CA).[17,36,37] The primary outcome was a firearm injury event identified through emergency department visit, hospitalization, or death certificate. Secondary outcomes were 1) the intent of the firearm injury, including: unintentional, assault, self-harm/suicide, and undetermined and 2) the weapon type:

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handgun, rifle, non-powdered firearm, and undetermined or unspecified (Appendix A, Firearm Codes). For each injury event, we measured the place of injury, nature of the injury (e.g., fracture, contusion), and type (location) of injury (e.g. traumatic brain injury, extremity, thorax) using International Classification of Diseases, 10th Revision codes. Individuals with an emergency department visit resulting in hospitalization or death were considered a single event. Death by firearm out-of-hospital was only available until December 31st, 2016, so these deaths due to injury were not captured in the last 15 months of the 15-year study period. In Canada, non-powdered firearms are considered firearms under Canada's Firearms Act only if the muzzle velocity exceeds 152.4 metres/second (m/s) and the muzzle energy surpasses 5.7 joules.[38] Nonetheless, firearms with projectile velocities of 75 m/s can penetrate eyes[39] and, depending on the mass of the bullet, can penetrate skin at 53 m/s[40] – thresholds far below those that are regulated. Further, what constitutes the legal definition of a firearm in health data varies by jurisdiction with legal definitions in the United States including only those with chemical combustion for a projectile and in Australia including non-powdered weapons without specification about muzzle velocities.[41,42] We included non-powdered firearms based on their mechanism of generating a projectile, not on the velocity or energy of the projectile.

Covariates

Covariates included age, sex, neighbourhood material deprivation quintile measured using the Ontario Marginalization Index[43], neighbourhood level income quintile, immigration status, rurality using the Rurality Index of Ontario[44], and hospital type at initial presentation (i.e., pediatric teaching, non-pediatric teaching, community hospitals).

Statistical Analyses

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Baseline characteristics of individuals injured versus killed by firearm were compared and reported as numbers and proportions. Crude and strata-specific rates of injury by weapon type, intent and socio-demographic characteristics were calculated using the corresponding Ontario population as the denominator. Multivariable Poisson regression models were used to estimate rate ratios with 95% confidence intervals [CIs] with weapon type as the primary exposure and age and sex as covariates. Separate regression models were used for each then used for injury intent.

All analyses were conducted using SAS 9.4 for Unix (SAS version 9.4, SAS Institute Inc.). Cell sizes less than 6 were not reportable because of Ontario privacy regulations.

Ethics Approval

Use of these data was authorized under Section 45 (1) of Ontario's Personal Health Information Protection Act. This does not require review by a Research Ethics Board. This study was approved by the ICES privacy office (ICES logged study: 2020 0990 246 000).

Results

Over the 15-year study period, there were 5,486 children and youth in Ontario injured or killed by firearms, with most (90.7%) of those injured surviving (Table 1). Most injuries and deaths occurred in males (90.1%) and in those between 18 and 24 years (61.5%). Individuals living in low-income neighbourhoods (i.e., quintile of 2 and below) accounted for over half (56.3%) of all firearm injuries and deaths. Similarly, neighbourhoods with high material deprivation (i.e., quintile 4 and above) accounted for over half (55.6%) of all firearm injuries and deaths. Most firearm-related injuries and deaths occurred in major urban centres (65.1%). Most injuries were

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unintentional (n = 3,416, 62.3%), and a quarter (n = 1,452, 26.5%) were from assault. Self-harm accounted for 204 (3.7%) cases, and legal intervention accounted for 61 (1.1%) cases. There were 353 (6.4%) injuries from an undetermined intent. Non-powdered firearms accounted for almost half (48.6%) of all firearm injuries and 41.7% of firearms were from an unspecified weapon type. Just over half of the total injuries presented at community hospitals (58.6%), followed by non-pediatric teaching hospitals (31.2%).

Characteristics of firearm injuries and deaths are presented in Table 2. Most injury events occurred in non-specified locations (76.4%); however, 9.2% occurred at home and 5.4% occurred on the street. Two-thirds (66.3%) of firearm injuries among survivors were open wounds, with a small proportion (12.7%) only causing superficial injuries yet still required emergency room care. One-third (33.6%) were either traumatic brain or head injuries and approximately half (44.9%) were to areas of the body with vital organs including the trunk, thorax and head (i.e., non-extremity injuries).

Males disproportionately experience firearm injuries from non-powdered firearms (6.76 per 100,000 population) and unspecified firearms (6.49 per 100,000 population) (Table 3). Adolescents between the ages of 13 and 17 years had the highest rate of firearm injury from non-powdered firearms (6.91 per 100,000 population) and emerging adults, 18 to 24 years, had the highest rate of handgun injuries (1.63 per 100,000 population). Across all weapon types, those in the lowest income quintile had the highest injury rates. Handgun and unspecified firearm type injuries occurred most in major urban areas with rifle and non-powdered firearm injury rates highest among those living in rural areas.

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For unintentional firearm injuries, highest rates were observed for non-powdered firearms and unspecified firearms, especially amongst adolescents 13 to 17 years (5.72 per 100,000 population). Males disproportionately experienced the greatest risk of unintentional-related firearm injuries from non-powdered firearms (5.39 per 100, 000 population) compared to females (0.63 per 100,000 population). Assault rates were highest from handguns (0.43 per 100,000 population) and non-powdered firearms (0.39 per 100,000 population). While assaults from handguns were most common among males and those living in urban and low-income neighbourhoods, non-powdered firearm injuries were also greatest in these groups.

Firearm injuries from self-harm occurred most often in adolescent and emerging adult males with few differences by socio-demographic characteristics. While rare relative to other intents, self-inflicted firearm injuries had the highest case-fatality rate (72.0%).

In the adjusted regression models (Table 4), individuals under 12 years of age and those aged 13-17 years were significantly less likely to be injured by a firearm than individuals aged 18 to 24 years, regardless of the injury intent. Similarly, across all models, females were less likely to be injured by a firearm compared to males. The risk of unintentional and unspecified firearm injury was higher for non-powdered firearm injury (adjusted rate ratio 1.53 [95% CI 1.42, 1.64] and 2.20 [95% CI 1.73, 2.80], respectively). The risk of unintentional firearm injury was 8.34 times higher for non-powdered firearms compared to handguns in the unadjusted model and 14.75 times higher in the adjusted model. Similar, but not as strong, results were found for unspecified firearm injury. In the adjusted model, only small differences were observed in assaults by non-powdered firearms compared to handguns.

Discussion

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In this population-based study, we found that 5,486 children and youth up to 24 years of age between 2003 and 2017 were injured or killed by a firearm in Ontario, Canada. This is equivalent to a mean of 366 firearm injuries annually and a rate of firearm injuries of 8.7 per 100,000 population. Non-powdered firearms made up the largest proportion of firearm injuries overall, whereas rifles were responsible for almost twice the number of deaths as handguns when the weapon type was identified. Almost two thirds of all injuries were unintentional and almost one quarter were from an assault. Most injuries were to boys or young men and those living in either low income or urban neighbourhoods. Almost half of all injuries were to the head, thorax, or abdomen with only a minority causing superficial injuries. Our findings highlight the magnitude and characteristics of firearm injuries among youth in Ontario, Canada and these numbers suggest firearm injuries are a serious and potentially preventable public health problem.

This study underscores the significant variation in firearm injury rates by jurisdiction. In the United States, firearm injury rates among children are reported to be between 19 to 23.5 injuries per 100,000 individuals.[30,45] Prior to this work, little data are published on children and youth outside of the United States, making other cross-jurisdictional comparisons difficult.[1,13,30,46] Similar to American studies, we found males to be at greatest risk of firearm injuries, especially as they emerge into adulthood.[13,37] Also similar to American studies, where reported, we found that most injuries occurred at home. It has been well demonstrated that injury risk from all intents is highest where there are firearms in the household. This further emphasizes the importance of adherence to safe storage practices and supports child access prevention laws designed to reduce firearm injury.[47] Like others, we demonstrate children and youth living in low-income neighbourhoods experience the highest proportion of firearm injuries.[48,49] This finding was observed across all weapons and intents suggesting a need to improve community

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safety and target such communities for firearm safety, education, and enforcement of existing legislation.[30,48]

We showed that 1.9% of unintentional and 18.7% of assault-related firearm injuries are fatal with an overall fatality rate of 9.3%. This is consistent with other reported fatality rates in youth, ranging from 2 to 12%.[45,48,50,51] The high proportion of children and youth who do not die of their injuries highlights that firearm injury surveillance must include survivors, as reporting only deaths vastly underestimates the burden of the issue.[1] Further, most of these were open wounds and to the head and torso. These 'near misses' present an opportunity for action, including potential for mandatory eye and thoracic protection while using such weapons.

Among those with self-inflicted injuries, 72.0% died, demonstrating that in this context firearms are a highly lethal injury mechanism. We have previously reported 12% of suicide deaths in Ontario youth occur by firearm.[52] Eliminating access to firearms for those experiencing mental illness or distress may help to reduce both attempted and completed suicides by firearm.[53] There were 14.7% of self-inflicted firearm injuries from non-powdered firearms with risk of injury not different from those from handguns or rifles. This suggests access to non-powdered firearms must also be considered when counselling youth with mental health concerns at risk for intentional self-injury. In the current study, rifles were involved in 28.7% of self-inflicted injuries, a proportion almost identical to that described by Hanlon et al.[54]

A high number of unintentional injuries in this study were from non-powdered firearms. Young children under 12 years have a disproportionate risk of firearm injury by non-powdered firearms (73.8% of all firearm injuries) with a still important proportion affecting adolescents (59.6%) and emerging adults (32%). [55] Others have shown non-powdered firearms injuries cause morbidity,

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especially to the eyes[39], and depending on the mass of the bullet, can penetrate skin at 53 m/s.[40] Most prior studies on non-powdered firearms have been small, single centred, or limited to pediatric hospitals only.[41,56,57] However, one US study using a nationally representative sample showed children have 13,486 visits to emergency departments annually for non-powdered firearms.[57] Regulations and legislation around possession, acquisition, use and transport of non-powdered firearms vary considerably by jurisdiction. In the US, some jurisdictions have adopted laws to address safety concerns with some states defining non-powered firearms as firearms subject to the same or similar regulations.[55,57] In Canada, lower velocity (<152.4 metres per second) firearms do not fall under the Canada Firearms Act, nor are they regulated by the Consumer Protection and Safety Act. There is no mandatory training, supervision, or equipment required. Given the number of injuries associated with these weapons, increased regulation of non-powdered firearms, particularly for minors, may be warranted.

Understanding factors related to firearm injuries in varying jurisdictions is important for informing strategies for prevention. While the scale of the issue may be different, there may be opportunities to learn from leading jurisdictions in terms of successful injury prevention strategies. Diversity in firearm regulations and legislation and corresponding injury rates as seen in the United States, Australia, Canada and Japan, points to a need to consider adopting firearm injury prevention approaches used in jurisdictions with low rates of injury.[25-29,58]

Strengths and Limitations

This is the largest population-based study in Canada to examine the extent of firearm injuries in youth, with specific attention to weapon type. While data used have validated codes for intent and weapon type, we do not report data on perpetrators and have limited data on the

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circumstances surrounding the injury. Many firearm injuries were of undetermined intent and weapon type, highlighting the need for better firearm injury surveillance to be able to measure if strategies to reduce injury are effective. Further, because of there was a high degree of missingness for the weapon type, the proportional contribution of each weapon type may be over or underestimated. There is wide variation in firearm ownership and weapon type across Canada and rates of injury are likely higher in regions with greater firearm ownership. Our measures likely underestimate the true burden of injury, especially for milder injuries from non-powdered firearms that may not present to a hospital.

Conclusions

We report weapon type and intent of firearm injuries among youth in Ontario. Where the intent was known, approximately two-thirds were unintentional and likely preventable with appropriate and enforced firearm safety standards for youth. Firearm injuries with non-powdered firearms are concerningly high and assaults and self-injury contributed to substantial firearm-related deaths and must be a focus of ongoing injury prevention efforts and surveillance for youth.

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Table 1. Baseline characteristics of children and emerging adults (0 to 24 years) who experienced a firearm injury in Ontario, Canada, 2003 to 2017. All numbers n (%) unless otherwise specified.

Variable		Firearm injury survivor	Firearm deaths	Total injuries and deaths
Overall		4,976 (90.7)	510 (9.3)	5,486
Age, years				
	0 to 12	548 (11.0)	7 (1.4)	555 (10.1)
	13 to 17	1,464 (29.4)	92 (18.0)	1,556 (28.4)
	18 to 24	2,964 (59.6)	411 (80.6)	3,375 (61.5)
	Mean ± SD	17.9 ± 4.3	20.0 ± 3.0	18.1 ± 4.2
	Median (IQR)	19 (15-21)	20 (18-22)	19 (16-21)
Sex				
	Female	509 (10.2)	36 (7.1)	545 (9.9)
	Male	4,467 (89.8)	474 (92.9)	4,941 (90.1)
Neighbourhood income quintile				
	1 (low)	1,689 (33.9)	217 (42.5)	1,906 (34.7)
	2	1,069 (21.5)	114 (22.4)	1,183 (21.6)
	3	887 (17.8)	86 (16.9)	973 (17.7)
	4	774 (15.6)	57 (11.2)	831 (15.1)
	5 (high)	*520-524	*31-35	555 (10.1)
	Missing	*33-37	*1-5	38 (0.7)
Neighbourhood material deprivation quintile				
	1 (low)	546 (11.0)	33 (6.5)	579 (10.6)
	2	683 (13.7)	64 (12.5)	747 (13.6)
	3	863 (17.3)	71 (13.9)	934 (17.0)
	4	968 (19.5)	93 (18.2)	1,061 (19.3)
	5 (high)	1,755 (35.3)	236 (46.3)	1,991 (36.3)
	Missing	161 (3.2)	13 (2.5)	174 (3.2)
Rurality				
	Major urban centre	3,174 (63.8)	395 (77.5)	3,569 (65.1)
	Urban	1,141 (22.9)	54 (10.6)	1,195 (21.8)
	Rural	505 (10.1)	45 (8.8)	550 (10.0)
	Missing	156 (3.1)	16 (3.1)	172 (3.1)
Immigrant status				
	Non-refugee immigrants	387 (7.8)	64 (12.5)	451 (8.2)
	Non-immigrants	4,380 (88.0)	418 (82.0)	4,798 (87.5)
	Refugee immigrants	209 (4.2)	28 (5.5)	237 (4.3)
Hospital type at presentation				
	Community	3,162 (63.5)	55 (10.8)	3,217 (58.6)
	Pediatric	*232-236	*1-5	237 (4.3)
	Teaching	*1578-1582	*130-134	1,712 (31.2)
	None	0 (0.0)	320 (62.7)	320 (5.8)
Firearm type				
	Handgun	343 (6.9)	*39-43	383 (7.0)
	Rifle	269 (5.4)	69 (13.5)	338 (6.2)
	BB guns/non-powdered firearm	*2412-2416	*1-5	2,417 (44.1)
	Unspecified firearm	1,907 (38.3)	380 (74.5)	2,287 (41.7)
Injury intent				
	Unintentional	3,351 (67.3)	65 (12.7)	3,416 (62.3)
	Assault	1,180 (23.7)	272 (53.3)	1,452 (26.5)
	Self-harm	57 (1.1)	147 (28.8)	204 (3.7)
	Undetermined	347 (7.0)	6 (1.2)	353 (6.4)
	Legal intervention	41 (0.8)	20 (3.9)	61 (1.1)

*Small cell sizes (<6) have been suppressed and combined with largest group to prevent back calculation as per institutional policy.

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Table 2. Characteristics of firearm injury for children and emerging adults (0 to 24 years) in Ontario, Canada, 2003 to 2017. All numbers n (%).

				Weapon Type				
	Firearm injury survivor	Firearm deaths	Total injuries and deaths	Handguns	Rifles	BB guns or non-powdered firearm	Legal	Other or Unspecified
Place of injury								
Home	476 (9.6)	31 (6.1)	507 (9.2)	* 42 - 46	46 (13.6)	246 (10.2)	*1 - 5	168 (7.3)
School	*30-34	*1-5	35 (0.6)	*1 - 5	*1 - 5	9 (0.4)	0 (0.0)	19 (0.8)
Athletic facility	*22-26	*1-5	27 (0.5)	*1 - 5	*1 - 5	*1 - 5	0 (0.0)	18 (0.8)
Street	275 (5.5)	23 (4.5)	298 (5.4)	44 (11.5)	* 13 - 17	53 (2.2)	*1 - 5	183 (8.0)
Trade	*133-137	*1-5	138 (2.5)	* 15 - 19	*1 - 5	26 (1.1)	0 (0.0)	92 (4.0)
Farm	12 (0.2)	0 (0.0)	12 (0.2)	0 (0.0)	*1 - 5	7 (0.3)	0 (0.0)	*1 - 5
Other/not specified	4,073 (81.9)	121 (23.7)	4,194 (76.4)	282 (73.6)	220 (65.1)	2,103 (87.0)	19 (31.1)	1,570 (68.6)
Nature of injury								
Fracture	685 (13.8)	27 (5.3)	712 (13.0)	121 (31.6)	73 (21.6)	45 (1.9)	13 (21.3)	460 (20.1)
Internal organ injury	434 (8.7)	76 (14.9)	510 (9.3)	97 (25.3)	44 (13.0)	10 (0.4)	17 (27.9)	342 (15.0)
Open wound	3,300 (66.3)	215 (42.2)	3,515 (64.1)	262 (68.4)	194 (57.4)	1,559 (64.5)	36 (59.0)	1,464 (64.0)
Amputation	16 (0.3)	0 (0.0)	16 (0.3)	*1 - 5	*1 - 5	*1 - 5	0 (0.0)	8 (0.3)
Blood vessel	114 (2.3)	19 (3.7)	133 (2.4)	26 (6.8)	11 (3.3)	*1 - 5	*1 - 5	90 (3.9)
Superficial contusion	*689-693	*1-5	694 (12.7)	19 (5.0)	20 (5.9)	494 (20.4)	6 (9.8)	155 (6.8)
Effect of foreign bodies entering orifice	72 (1.4)	0 (0.0)	72 (1.3)	0 (0.0)	*5 - 9	50 (2.1)	*1 - 5	13 (0.6)
Other specified	400 (8.1)	21 (4.1)	421 (7.7)	51 (13.3)	35 (10.3)	116 (4.8)	12 (19.7)	209 (9.1)
Unspecified	370 (7.4)	4 (0.8)	374 (6.8)	8 (2.1)	9 (2.7)	240 (9.9)	0 (0.0)	117 (5.1)
Type of injury								
Traumatic brain	849 (17.1)	107 (21.0)	956 (17.4)	* 66 - 70	85 (25.1)	512 (21.2)	*1 - 5	288 (12.6)
Head (no brain)	883 (17.7)	6 (1.2)	889 (16.2)	* 20 - 24	34 (10.1)	645 (26.6)	*1 - 5	185 (8.1)
Neck	155 (3.1)	22 (4.3)	177 (3.2)	18 (4.7)	* 8 - 12	58 (2.4)	*1 - 5	88 (3.8)
Thorax	384 (7.7)	105 (20.6)	489 (8.9)	62 (16.2)	29 (8.6)	64 (2.6)	20 (32.8)	314 (13.7)
Vertebral column/Spine	119 (2.4)	12 (2.4)	131 (2.4)	28 (7.3)	*7 - 11	*1-5	*1 - 5	87 (3.8)
Abdomen, lower back, pelvis	826 (16.4)	86 (16.9)	912 (16.7)	146 (38.1)	59 (17.4)	74 (3.0)	27 (44.2)	606 (26.5)
Upper extremity	1,504 (30.2)	27 (5.3)	1,531 (27.9)	125 (32.6)	81 (24.0)	749 (31.0)	18 (29.5)	558 (24.4)
Lower extremity	1,238 (24.9)	18 (3.5)	1,256 (22.9)	126 (32.9)	74 (21.9)	363 (15.0)	13 (21.3)	680 (29.7)
Multiple/system wide region	102 (2.0)	23 (4.5)	125 (2.3)	18 (4.7)	14 (4.2)	*8-16	*1 - 5	76 (3.3)
Unspecified region	*50-54	*1-5	55 (1.0)	*1 - 5	0 (0.0)	11 (0.5)	*1 - 5	42 (1.8)

*Small cell sizes (<6) have been suppressed and combined with largest group to prevent back calculation as per institutional policy.

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Table 3. Firearm injuries among children and emerging adults (0 to 24 years) in Ontario, Canada, 2003 to 2018 by weapon type and intent. All numbers n, (rate per 100,000 population).

	Overall	Age, years			Sex		Income Quintile		Rurality		
	total	0-12	13-17	18-24	Female	Male	Lowest	Highest	Major Urban	Urban	Rural
Overall											
Handgun	383 (0.61)	6 (0.02)	59 (0.44)	318 (1.63)	32 (0.11)	351 (1.10)	193 (1.56)	24 (0.19)	351 (0.77)	19 (0.16)	11 (0.26)
Rifle	338 (0.54)	22 (0.07)	80 (0.60)	236 (1.21)	42 (0.14)	296 (0.93)	97 (0.78)	41 (0.32)	187 (0.41)	77 (0.64)	52 (1.22)
BB gun	2,417 (3.88)	410 (1.40)	927 (6.91)	1,080 (5.53)	257 (0.85)	2,160 (6.76)	628 (5.08)	337 (2.64)	1,129 (2.49)	825 (6.90)	359 (8.44)
Unspecified	2,287 (3.67)	116 (0.39)	480 (3.58)	1,691 (8.66)	214 (0.70)	2,073 (6.49)	970 (7.85)	150 (1.17)	1,861 (4.11)	260 (2.18)	125 (2.94)
Firearm Injuries by Intent											
Unintentional											
Handgun	96 (0.15)	-	23 (0.14)	73 (0.37)	17 (0.06)	79 (0.25)	41 (0.33)	8 (0.06)	79 (0.17)	11 (0.09)	6 (0.14)
Rifle	161 (0.26)	15 (0.05)	41 (0.31)	105 (0.54)	28 (0.09)	133 (0.42)	45 (0.36)	26 (0.20)	70 (0.15)	49 (0.41)	30 (0.71)
BB gun	1,913 (3.07)	340 (1.16)	767 (5.72)	806 (4.13)	192 (0.63)	1,721 (5.39)	479 (3.88)	273 (2.14)	841 (1.86)	683 (5.71)	304 (7.15)
Unspecified	1,246 (2.00)	98 (0.33)	281 (2.10)	867 (4.44)	125 (0.41)	1,121 (3.51)	503 (4.07)	96 (0.75)	947 (2.09)	190 (1.59)	85 (2.00)
Assault											
Handgun	265 (0.43)	-	36 (0.25)	229 (1.17)	13 (0.04)	252 (0.79)	143 (1.16)	12 (0.09)	257 (0.56)	6 (0.05)	-
Rifle	94 (0.15)	-	14 (0.09)	80 (0.41)	-	94 (0.28)	36 (0.29)	-	83 (0.18)	8 (0.07)	-
BB gun	246 (0.39)	38 (0.13)	81 (0.60)	127 (0.65)	41 (0.13)	205 (0.64)	73 (0.59)	27 (0.21)	151 (0.33)	64 (0.54)	20 (0.47)
Unspecified	847 (1.3)	9 (0.03)	151 (1.13)	687 (3.52)	67 (0.22)	780 (2.44)	410 (3.32)	37 (0.29)	811 (1.78)	29 (0.24)	-
Self-harm											
Handgun	13 (0.02)	-	-	13 (0.05)	-	13 (0.04)	-	-	13 (0.02)	-	-
Rifle	59 (0.09)	-	19 (0.13)	40 (0.20)	-	59 (0.17)	12 (0.10)	8 (0.06)	26 (0.06)	15 (0.13)	13 (0.31)
BB gun	30 (0.05)	-	11 (0.05)	19 (0.10)	-	30 (0.09)	9 (0.07)	-	15 (0.03)	14 (0.11)	-
Unspecified	102 (0.16)	-	22 (0.16)	80 (0.41)	11 (0.04)	91 (0.28)	23 (0.19)	10 (0.08)	43 (0.09)	28 (0.23)	25 (0.59)
Undetermined											
Handgun	9 (0.01)	-	-	9 (0.04)	-	9 (0.03)	7 (0.06)	-	9 (0.02)	-	-
Rifle	24 (0.04)	-	13 (0.07)	11 (0.06)	-	24 (0.06)	-	-	15 (0.02)		7 (0.16)
BB gun	228 (0.37)	28 (0.10)	72 (0.54)	128 (0.66)	22 (0.07)	206 (0.64)	67 (0.54)	33 (0.26)	122 (0.27)	65 (0.54)	34 (0.80)
Unspecified	92 (0.15)	9 (0.03)	26 (0.19)	57 (0.29)	11 (0.04)	81 (0.25)	34 (0.28)	7 (0.05)	65 (0.14)	13 (0.11)	10 (0.24)

*Small cell sizes (<6) have been suppressed and combined with largest group in row to prevent back calculation as per institutional policy.
Legal intervention not included due to small cell sizes.

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Table 4. Rate ratios of firearm injuries by intent for children and emerging adults (0 to 24 years) in Ontario, Canada, 2003 to 2018.

Variable	Model 1				Model 2			
	Unintentional injuries	Assault-related injuries	Self-harm injuries	Unspecified injuries	Unintentional injuries	Assault-related injuries	Self-harm injuries	Unspecified injuries
	RR ($CI_{95\%}$)	RR ($CI_{95\%}$)	RR ($CI_{95\%}$)	RR ($CI_{95\%}$)	RR ($CI_{95\%}$)	RR ($CI_{95\%}$)	RR ($CI_{95\%}$)	RR ($CI_{95\%}$)
Weapon Type								
Handgun	0.17 (0.14-0.21)	0.51 (0.44-0.58)	0.47 (0.26-0.83)	0.56 (0.28-1.14)	0.10 (0.08-0.13)	0.34 (0.30-0.40)	0.40 (0.22-0.71)	0.39 (0.19-0.77)
Rifle	0.19 (0.16-0.22)	0.24 (0.19-0.29)	0.63 (0.45-0.87)	0.55 (0.35-0.87)	0.15 (0.13-0.75)	0.14 (0.11-0.17)	0.58 (0.42-0.80)	0.53 (0.34-0.84)
BB gun	1.42 (1.32-1.52)	0.26 (0.23-0.30)	0.39 (0.26-0.58)	1.85 (1.45-2.36)	1.53 (1.42-1.64)	0.29 (0.25-0.33)	0.41 (0.26-0.61)	2.20 (1.73-2.81)
Unspecified (ref)	1.00	---	---	---	--	--	--	--
Age								
0-12					0.18 (0.16-0.20)	0.08 (0.06-0.11)	0.34 (0.14-0.87)	0.21 (0.15-0.29)
13-17					0.88 (0.82-0.95)	0.39 (0.34-0.44)	0.83 (0.61-1.15)	0.89 (0.71-1.13)
18-24 (ref)					1.00	--	--	--
Sex								
Female					0.14 (0.12-0.15)	0.14 (0.11-0.17)	0.37 (0.22-0.60)	0.39 (0.28-0.54)
Male (ref)					1.00	--	--	--
Contrasts								
Rifles vs Handgun	1.12 (0.87-1.45)	0.47 (0.37-0.59)	1.34 (0.74-2.44)	0.98 (0.46-2.12)	1.43 (1.11-1.84)	0.40 (0.32-0.50)	1.47 (0.80-2.68)	1.38 (0.64-2.97)
BB guns vs Handgun	8.34 (6.79-10.23)	0.52 (0.44-0.62)	0.83 (0.43-1.58)	3.29 (1.69-6.41)	14.75 (12.01-18.12)	0.84 (0.70-1.00)	1.01 (0.52-1.95)	5.68 (2.90-11.11)
Unspecified vs Handgun	5.88 (4.78-7.24)	1.98 (1.72-2.27)	2.14 (1.20-3.81)	1.78 (0.90-3.53)	9.65 (7.84-11.88)	2.90(2.53-3.33)	2.52 (1.41-4.50)	2.58 (1.30-5.13)

Note. CI = confidence interval; Ref = reference category; RR = rate ratio; Model 1 includes firearm type only. Model 2 adds in covariates (i.e., age and sex).

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APPENDIX

FIREARM INJURIES

W32: Handgun discharge
W33: Rifle, shotgun and larger firearm discharge
W3400: Discharge from BB gun
W3401: Discharge from air gun
W3408: Discharge from other specified firearms
W3409: Discharge from unspecified firearm

X93: Assault by handgun discharge
X94: Assault by rifle, shotgun & larger firearm discharge
X9500: Assault by BB gun discharge
X9501: Assault by air gun discharge
X9508: Assault by other specified firearm discharge
X9509: Assault by unspecified firearm discharge

X72: Intentional self-harm by handgun discharge
X73: Intentional self-harm by rifle, shotgun & larger firearm discharge
X7400: Intentional self-harm BB gun discharge
X7401: Intentional self-harm air gun discharge
X7408: Intentional self-harm other specified firearm discharge
X7409: Intentional self-harm by unspecified firearm discharge

Y22: Handgun discharge undetermined intent
Y23: Rifle shotgun & larger firearm discharge undetermined intent
Y2400: BB gun discharge, undetermined intent
Y2401: Air gun discharge, undetermined intent
Y2408: Other specified firearm discharge, undetermined intent
Y2409: Unspecified firearm discharge, undetermined intent

Y35.0 - Legal intervention involving firearm discharge

INTENT

Unintentional Firearm Injury (ORGD only use the first 3 digits W32, W33, W34)
W32: Handgun discharge
W33: Rifle, shotgun and larger firearm discharge
W3400: Discharge from BB gun
W3401: Discharge from air gun
W3408: Discharge from other specified firearms
W3409: Discharge from unspecified firearm

Assault from firearm (intentional), ORGD only use the first 3 digits X93, X94, X95
X93: Assault by handgun discharge
X94: Assault by rifle, shotgun & larger firearm discharge
X9500: Assault by BB gun discharge
X9501: Assault by air gun discharge

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X9508: Assault by other specified firearm discharge
X9509: Assault by unspecified firearm discharge

Self-harm from firearm (suicide) ORGD only use the first 3 digits X72, X73, X74
X72: Intentional self-harm by handgun discharge
X73: Intentional self-harm by rifle, shotgun & larger firearm discharge
X7400: Intentional self-harm BB gun discharge
X7401: Intentional self-harm air gun discharge
X7408: Intentional self-harm other specified firearm discharge
X7409: Intentional self-harm by unspecified firearm discharge

Intent unknown (undetermined) ORGD only use the first 3 digits Y22, Y23, Y24
Y22: Handgun discharge undetermined intent
Y23: Rifle shotgun & larger firearm discharge undetermined intent
Y2400: BB gun discharge, undetermined intent
Y2401: Air gun discharge, undetermined intent
Y2408: Other specified firearm discharge, undetermined intent
Y2409: Unspecified firearm discharge, undetermined intent

Legal Interventions
Y35.0 - Legal intervention involving firearm discharge

If there were multiple intents in one injury episode, the following rules were used to decide the intent
Assault*intent unknown = assault
Assault*legal intervention = assault
Self-harm*intent unknown = self-harm
Unintentional*assault = assault
Unintentional*assault*legal intervention = assault
Unintentional*intent unknown = unintentional
Unintentional*legal intervention = unintentional
Unintentional*self-harm = self-harm.

WEAPON TYPE
Handgun
W32: Handgun discharge
X93: Assault by handgun discharge
X72: Intentional self-harm by handgun discharge
Y22: Handgun discharge undetermined intent

Rifle
W33: Rifle, shotgun and larger firearm discharge
X94: Assault by rifle, shotgun & larger firearm discharge
X73: Intentional self-harm by rifle, shotgun & larger firearm discharge
Y23: Rifle shotgun & larger firearm discharge undetermined intent

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BB Guns and Airgun
W3400: Discharge from BB gun
W3401: Discharge from air gun
X9500: Assault by BB gun discharge
X9501: Assault by air gun discharge
X7400: Intentional self-harm BB gun discharge
X7401: Intentional self-harm air gun discharge
Y2400: BB gun discharge, undetermined intent
Y2401: Air gun discharge, undetermined intent

Other and Unspecified
W3408: Discharge from other specified firearms
W3409: Discharge from unspecified firearm
X9508: Assault by other specified firearm discharge
X9509: Assault by unspecified firearm discharge
X7408: Intentional self-harm other specified firearm discharge
X7409: Intentional self-harm by unspecified firearm discharge
Y2408: Other specified firearm discharge, undetermined intent
Y2409: Unspecified firearm discharge, undetermined intent

Multiple weapons, the following rules apply:
BB*other = BB
Handgun*BB = First use hospitalization record, then use handgun
Handgun*other = Handgun
Handgun*rifle = First use hospitalization and then use handgun
Rifle*BB and Rifle*other = Rifle.

PLACE OF INJURY OCCURRENCE

Home or residential institution: U980, U981
School, other institution/public area: U982, U9820, U9828
Athletic areas: U983
Street/highway: U984
Trade/service/industrial/construction area: U985, U986
Farm: U987
Other/unspecified: U988, U989

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DATA SOURCES AND ASSOCIATED STUDY VARIABLES

Data source	Variables
Registered Person Database (RPDB)	Patient sex, residential postal code, date of birth
Immigration, Refugees and Citizenship Canada's Permanent Resident Database	Immigration status
Ontario Registrar General – Deaths	Death
National Ambulatory Care Reporting System	Emergency department visits, diagnoses
Canadian Institutes for Health Information Discharge Abstract Database	Hospitalizations, diagnoses
Ontario Marginalization Index	Material deprivation quintile
2016 Canadian Census	Rurality

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The RECORD statement – checklist of items, extended from the STROBE statement, that should be reported in observational studies using routinely collected health data.

	Item No.	STROBE items	Location in manuscript where items are reported	RECORD items	Location in manuscript where items are reported
Title and abstract					
	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 1, 4	RECORD 1.1: The type of data used should be specified in the title or abstract. When possible, the name of the databases used should be included. RECORD 1.2: If applicable, the geographic region and timeframe within which the study took place should be reported in the title or abstract. RECORD 1.3: If linkage between databases was conducted for the study, this should be clearly stated in the title or abstract.	Page 4
Introduction					
Background rationale	2	Explain the scientific background and rationale for the investigation being reported	Page 5		
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 6		
Methods					
Study Design	4	Present key elements of study design early in the paper	Page 7		
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 7		

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Participants	6	*(a) Cohort study* - Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study* - Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study* - Give the eligibility criteria, and the sources and methods of selection of participants *(b) Cohort study* - For matched studies, give matching criteria and number of exposed and unexposed *Case-control study* - For matched studies, give matching criteria and the number of controls per case	Page 8	RECORD 6.1: The methods of study population selection (such as codes or algorithms used to identify subjects) should be listed in detail. If this is not possible, an explanation should be provided. RECORD 6.2: Any validation studies of the codes or algorithms used to select the population should be referenced. If validation was conducted for this study and not published elsewhere, detailed methods and results should be provided. RECORD 6.3: If the study involved linkage of databases, consider use of a flow diagram or other graphical display to demonstrate the data linkage process, including the number of individuals with linked data at each stage.	Page 8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable.	Page 8, 9	RECORD 7.1: A complete list of codes and algorithms used to classify exposures, outcomes, confounders, and effect modifiers should be provided. If these cannot be reported, an explanation should be provided.	Page 8, 9, Appendix
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Page 8, 9		

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Bias	9	Describe any efforts to address potential sources of bias	Page 9		
Study size	10	Explain how the study size was arrived at	Page 8		
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	Page 8, 9		
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) *Cohort study* - If applicable, explain how loss to follow-up was addressed *Case-control study* - If applicable, explain how matching of cases and controls was addressed *Cross-sectional study* - If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses	Page 9		
Data access and cleaning methods		..		RECORD 12.1: Authors should describe the extent to which the investigators had access to the database population used to create the study population.	Page 3

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				RECORD 12.2: Authors should provide information on the data cleaning methods used in the study.	
Linkage		..		RECORD 12.3: State whether the study included person-level, institutional-level, or other data linkage across two or more databases. The methods of linkage and methods of linkage quality evaluation should be provided.	Page 8
Results					
Participants	13	(a) Report the numbers of individuals at each stage of the study (*e.g.*, numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed) (b) Give reasons for non-participation at each stage. (c) Consider use of a flow diagram	Page 10	RECORD 13.1: Describe in detail the selection of the persons included in the study (*i.e.,* study population selection) including filtering based on data quality, data availability and linkage. The selection of included persons can be described in the text and/or by means of the study flow diagram.	Page 10
Descriptive data	14	(a) Give characteristics of study participants (*e.g.*, demographic, clinical, social) and information on exposures and potential confounders (b) Indicate the number of participants with missing data for each variable of interest (c) *Cohort study* - summarise follow-up time (*e.g.*, average and total amount)	Page 10		
Outcome data	15	*Cohort study* - Report numbers of outcome events or summary measures over time *Case-control study* - Report numbers in each exposure	Page 10		

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		category, or summary measures of exposure *Cross-sectional study* - Report numbers of outcome events or summary measures			
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Page 10, 11		
Other analyses	17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	NA		
Discussion					
Key results	18	Summarise key results with reference to study objectives	Page 11		
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Page 12	RECORD 19.1: Discuss the implications of using data that were not created or collected to answer the specific research question(s). Include discussion of misclassification bias, unmeasured confounding, missing data, and changing eligibility over time, as they pertain to the study being reported.	Page 12
Interpretation	20	Give a cautious overall interpretation of results considering objectives,	Page 11, 12		

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		limitations, multiplicity of analyses, results from similar studies, and other relevant evidence			
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 12		
Other Information					
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 2		
Accessibility of protocol, raw data, and programming code		..		RECORD 22.1: Authors should provide information on how to access any supplemental information such as the study protocol, raw data, or programming code.	Page 3

*Reference: Benchimol EI, Smeeth L, Guttmann A, Harron K, Moher D, Petersen I, Sørensen HT, von Elm E, Langan SM, the RECORD Working Committee. The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) Statement. *PLoS Medicine* 2015; in press.

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Title: Firearm injury epidemiology in children and youth in Ontario, Canada: a population-based study.

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Conflict of Interest Disclosures: Natasha Saunders reports receiving an editorial honorarium from Archives of Diseases in Childhood and an honorarium from M.S.I. Foundation, outside the submitted work. Dr. David Gomez is a member of national and international medical associations that advocate for the reduction of firearm injuries: the American College of Surgeons, the Trauma Association of Canada and the Panamerican Trauma Society. In addition, David Gomez is a member of the Canadian Doctors for Protection from Guns, which is an advocacy group. The other authors received no external funding and have no relevant conflicts of interest to disclose.

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the original source of which is ServiceOntario. The views expressed therein are those of the authors and do not necessarily reflect those of ORG or Ministry of Government Services.

Data sharing: The data set from this study is held securely in coded form at ICES. Data-sharing agreements prohibit ICES from making the data set publicly available, but access may be granted to those who meet pre-specified criteria for confidential access, available at www.ices.on.ca/DAS. The full data set creation plan and underlying analytic code are available from the authors upon request, understanding that the programs may rely upon coding templates or macros that are unique to ICES.

Abbreviations: CI, confidence intervals; ED, Emergency Department

Contributors Statement: N. Saunders conceptualized and designed the study, interpreted the results, drafted the initial manuscript, revised the manuscript, and approved the final manuscript as submitted. C. Moore Hepburn, C. de Oliveira, R. Strauss, L. Fiksenbaum, P. Pageau, D. Gomez and A. Macpherson interpreted the results, revised the manuscript, and approved the final manuscript as submitted. A. Huang and Ning Liu had access to and analyzed the data, interpreted the results, revised the manuscript, and approved the final manuscript as submitted. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Keywords: Firearms, guns, injury, epidemiology, violence, suicide, trauma, pediatrics

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Abstract

Background and Objective: Despite firearms contributing to significant morbidity and mortality globally, firearm injury epidemiology is seldom described outside of the USA. We examined firearm injuries among youth in Canada, including weapon type, and intent.

Design: Population based, pooled cross-sectional study using linked health and administrative databases.

Setting: Ontario, Canada.

Participants: All children and youth from birth to 24-years, residing in Ontario from April 1, 2003 to March 31, 2018.

Exposure: Firearm injury intent and weapon type using the International Classification of Disease-10 CM Codes with Canadian enhancements. Secondary exposures were socio-demographics including age, sex, rurality and income.

Main Outcomes: Any hospital or death record of a firearm injury with counts and rates of firearm injuries described overall and stratified by weapon type and injury intent. Multivariable Poisson regression stratified by injury intent was used to calculate rate ratios of firearm injuries by weapon type.

Results: Of 5,486 children and youth with a firearm injury (annual rate: 8.8/100,000 population), 90.7% survived. Most injuries occurred in males (90.1%, 15.5/100,000 population). 62.3% (3416) of injuries were unintentional (5.5/100,000 population) of which 1.9% were deaths, whereas 26.5% (1452) were assault related (2.3/100,00 population) of which 18.7% were deaths. Self-harm accounted for 3.7% (204) of cases of which 72.0% were deaths. Across all intents, adjusted regression models showed males were at an increased risk of injury. Non-powdered

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firearms accounted for half (48.6%, 3.9/100,000 population) of all injuries. Compared to handguns, non-powdered firearms had a higher risk of causing unintentional injuries (adjusted rate ratio [aRR] 14.75 95%CI 12.01, 18.12) but not assault (aRR 0.84 95%CI 0.70, 1.00).

Conclusions: Firearm injuries are a preventable public health problem among youth in Ontario, Canada. Unintentional injuries and those caused by non-powdered firearms were most common and assault and self-injury contributed to substantial firearm-related deaths and should be a focus of prevention efforts.

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Article Summary

Strengths of This Study

- This is a large population-based study with almost complete provincial coverage of children and youth..
- Beyond measuring injury intent, this study measures the weapon type that caused the firearm injury.
- Both in and out of hospital deaths, all hospitalizations, and all emergency department visits for firearm injuries in Ontario were captured in available data.
- This study distinguishes the type and nature of injuries caused by various firearms, demonstrating the severity of injuries by weapon type and intent.

Limitations of This Study

- While data used have validated codes for intent and weapon type, we do not report data on perpetrators and have limited data on the circumstances surrounding the injury.

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Introduction

Firearm injuries are an important cause of morbidity and mortality among youth in high-income countries.[1,2] Firearm injuries, in particular from assault and self-harm, can be fatal and, among survivors, leave lasting repercussions.[3-7] Firearms also carry the highest rate of lethal injury in those who attempt suicide. Children and youth are particularly vulnerable to firearm injury. It is a period in their lives where they have increasing independence, immature executive functioning, and potential access to firearms.[8]

The United States consistently leads with the highest rates of firearm homicide and suicide deaths among the Organization for Economic Co-operation and Development (OECD) countries, with Canada, Portugal and Ireland following next for per capita firearm homicides and Finland, Austria and France afterwards for per capita firearm suicides.[9] The majority of public health research related to pediatric firearm injuries is from the United States, where one third of households (and up to 61% in some states) own at least one firearm.[10,11] U.S. data reveals that only one third of families who own guns report storing their firearms safely[12] and that unintentional injuries represent one third of firearm injuries in American children[13], typically occurring either in or close to home.[14] In contrast, only approximately 17 to 34% of Canadian households own at least one firearm[15] and firearms are involved in 30% of homicides and 12% of suicides.[16]

Internationally recognized injury reporting standards categorize firearm injuries into one of five groups by intent: unintentional, intentional (assault), self-inflicted (suicide or attempted suicide), legal intervention (war, police shooting), and intent unknown, using validated diagnostic codes.[17-23] Firearms are also generally grouped into one of three types: handguns, rifles/long guns, and non-powdered firearms. Regulations around possession, acquisition, use, and transport

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of these weapons vary considerably by weapon type, yet all are capable of causing serious bodily harm, including death.[24]

In the United States, there is a strong inverse relationship between states with tighter firearm legislation, especially child access prevention laws, and firearm injury rates.[25,26] The same holds true in international jurisdictions where firearms are strictly regulated. In Australia and Japan, for example, non-powdered firearms (e.g., air guns or BB guns) require a licence to own and rifles and handguns are owned by a select few among whom use is tightly controlled.[27-29] In these jurisdictions, firearm injuries are now very low.[1]

The extent to which Canadian youth are affected by firearm injuries is not known and the sociocultural environment, drivers, and normative behaviours around firearms and legislation are unique and important to understand for firearm injury prevention globally. Further, firearms data are often presented as deaths, rather than injuries. Without accounting for all injuries, including emergency department visits and hospitalizations, firearm injuries and their sequelae on patient, families, and communities are grossly underestimated.[5,6,30] Finally, reports seldom describe the weapon type or specify intent. Consequently, the extent of firearm injuries and contributing factors are often inferred or not explored due to a paucity of detailed firearm injury data available.

To inform firearm injury prevention strategies for youth, the full scope of firearm injuries in this population must first be defined. It is also critical that we understand the rate of firearm injuries, the types of firearms are being used on victims of firearm injuries by intent, and the resulting types of injuries. Knowledge of the patterns of injury are essential to shape policies and programs to prevent firearm injury. Our objectives were to describe the epidemiology of firearm-related injuries among youth in Ontario, Canada using data from emergency departments,

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hospitals and death records, and to compare the risk of injury by weapon type and intent. We hypothesized that unintentional injuries and those from non-powdered firearms would account for the majority of injuries.

Methods

Study Design

We conducted a population-based cross-sectional study in Ontario, Canada's largest province where hospital and outpatient physician services are funded through provincial health insurance to the province's ~14 million residents. For context, Canada does not currently have a firearms registry, though, older data suggests wide variation in household firearm ownership rates with 67 percent of households in the Yukon and Northwest Territories, 15 percent of Ontario, and about 30 percent in Atlantic Canada.[31,32] We used linked health and administrative datasets housed at ICES (formerly The Institute for Clinical Evaluative Sciences), a not-for-profit research institute whose legal status under Ontario's health information privacy law allows it to collect and analyze health data without individual consent. Datasets are linked through encoded unique health identification numbers for all persons with provincial health insurance. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines.

Data Sources

To identify individuals with firearm injuries, we used diagnostic codes from provincial portions of hospital discharge (Canadian Institutes for Health Information Discharge Abstract Database), emergency department and same-day surgery (National Ambulatory Care Reporting System), and death (Ontario Registrar General – Vital Statistics, Deaths) databases. We used Ontario's

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health care registry, the Registered Persons Database, to obtain demographic data for all Ontario residents eligible for public health insurance and Immigration, Refugees and Citizenship Canada's Permanent Resident Database for immigration information. We linked individual level postal codes to Canadian census data to obtain neighbourhood level income and to determine rural or urban residence. ICES data are widely used and valid for sociodemographic characteristics, physician billing claims and primary hospital diagnoses.[33] Databases included and linkage rates are in the Appendix.[34]

Study Population

We included children and youth from birth to 24 years old living in Ontario, Canada from April 1st, 2003 to March 31st 2018 and eligible for provincial health insurance. The United Nations uses 24 years as the cut-off for defining youth and the Centre for Disease Control and Prevention (CDC) also uses up to 24 years to measure youth violence, and thus we did the same.[35,36]

Patient and public involvement

No patient involved.

Outcomes

The framework for measurement of firearm injury was based on the international framework for injury surveillance developed by the CDC and the World Health Organization (WHO), using the International Classification of Disease Clinical Modification 10 External Cause of Injury Codes for use in administrative data, with Canadian enhancements (ICD 10-CA).[17,37,38] The primary outcome was a firearm injury event identified through emergency department visit, hospitalization, or death certificate. Secondary outcomes were 1) the intent of the firearm injury, including: unintentional, assault, self-harm/suicide, and undetermined and 2) the weapon type:

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handgun, rifle, non-powdered firearm, and undetermined or unspecified (Appendix A, Firearm Codes). For each injury event, we measured the place of injury, nature of the injury (e.g., fracture, contusion), and type (location) of injury (e.g. traumatic brain injury, extremity, thorax) using International Classification of Diseases, 10th Revision codes. Individuals with an emergency department visit resulting in hospitalization or death were considered a single event. Death by firearm out-of-hospital was only available until December 31st, 2016, so these deaths due to injury were not captured in the last 15 months of the 15-year study period. In Canada, non-powdered firearms are considered firearms under Canada's Firearms Act only if the muzzle velocity exceeds 152.4 metres/second (m/s) and the muzzle energy surpasses 5.7 joules.[39] Nonetheless, firearms with projectile velocities of 75 m/s can penetrate eyes[40] and, depending on the mass of the bullet, can penetrate skin at 53 m/s[41] – thresholds far below those that are regulated. Further, what constitutes the legal definition of a firearm in health data varies by jurisdiction with legal definitions in the United States including only those with chemical combustion for a projectile and in Australia including non-powdered weapons without specification about muzzle velocities.[42,43] We included non-powdered firearms based on their mechanism of generating a projectile, not on the velocity or energy of the projectile.

Covariates

Covariates included age, sex, neighbourhood material deprivation quintile measured using the Ontario Marginalization Index[44], neighbourhood level income quintile, immigration status, rurality using the Rurality Index of Ontario[45], and hospital type at initial presentation (i.e., pediatric teaching, non-pediatric teaching, community hospitals).

Statistical Analyses

For peer review only

Baseline characteristics of individuals injured versus killed by firearm were compared and reported as numbers and proportions. Crude and strata-specific rates of injury by weapon type, intent and socio-demographic characteristics were calculated using the corresponding Ontario population as the denominator. Multivariable Poisson regression models were used to estimate rate ratios with 95% confidence intervals [CIs] with weapon type as the primary exposure and age and sex as covariates. Separate regression models were used for each then used for injury intent.

All analyses were conducted using SAS 9.4 for Unix (SAS version 9.4, SAS Institute Inc.). Cell sizes less than 6 were not reportable because of Ontario privacy regulations.

Ethics Approval

Use of these data was authorized under Section 45 (1) of Ontario's Personal Health Information Protection Act. This does not require review by a Research Ethics Board. This study was approved by the ICES privacy office (ICES logged study: 2020 0990 246 000).

Results

Over the 15-year study period, there were 5,486 children and youth in Ontario injured or killed by firearms, with most (90.7%) of those injured surviving (Table 1). Most injuries and deaths occurred in males (90.1%) and in those between 18 and 24 years (61.5%). Individuals living in low-income neighbourhoods (i.e., quintile of 2 and below) accounted for over half (56.3%) of all firearm injuries and deaths. Similarly, neighbourhoods with high material deprivation (i.e., quintile 4 and above) accounted for over half (55.6%) of all firearm injuries and deaths. Most firearm-related injuries and deaths occurred in major urban centres (65.1%). Most injuries were

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unintentional (n = 3,416, 62.3%), and a quarter (n = 1,452, 26.5%) were from assault. Self-harm accounted for 204 (3.7%) cases, and legal intervention accounted for 61 (1.1%) cases. There were 353 (6.4%) injuries from an undetermined intent. Non-powdered firearms accounted for almost half (48.6%) of all firearm injuries and 41.7% of firearms were from an unspecified weapon type. Just over half of the total injuries presented at community hospitals (58.6%), followed by non-pediatric teaching hospitals (31.2%).

Characteristics of firearm injuries and deaths are presented in Table 2. Most injury events occurred in non-specified locations (76.4%); however, 9.2% occurred at home and 5.4% occurred on the street. Two-thirds (66.3%) of firearm injuries among survivors were open wounds, with a small proportion (12.7%) only causing superficial injuries yet still required emergency room care. One-third (33.6%) were either traumatic brain or head injuries and approximately half (44.9%) were to areas of the body with vital organs including the trunk, thorax and head (i.e., non-extremity injuries).

Males disproportionately experience firearm injuries from non-powdered firearms (6.76 per 100,000 population) and unspecified firearms (6.49 per 100,000 population) (Table 3). Adolescents between the ages of 13 and 17 years had the highest rate of firearm injury from non-powdered firearms (6.91 per 100,000 population) and emerging adults, 18 to 24 years, had the highest rate of handgun injuries (1.63 per 100,000 population). Across all weapon types, those in the lowest income quintile had the highest injury rates. Handgun and unspecified firearm type injuries occurred most in major urban areas with rifle and non-powdered firearm injury rates highest among those living in rural areas.

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For unintentional firearm injuries, highest rates were observed for non-powdered firearms and unspecified firearms, especially amongst adolescents 13 to 17 years (5.72 per 100,000 population). Males disproportionately experienced the greatest risk of unintentional-related firearm injuries from non-powdered firearms (5.39 per 100, 000 population) compared to females (0.63 per 100,000 population). Assault rates were highest from handguns (0.43 per 100,000 population) and non-powdered firearms (0.39 per 100,000 population). While assaults from handguns were most common among males and those living in urban and low-income neighbourhoods, non-powdered firearm injuries were also greatest in these groups.

Firearm injuries from self-harm occurred most often in adolescent and emerging adult males with few differences by socio-demographic characteristics. While rare relative to other intents, self-inflicted firearm injuries had the highest case-fatality rate (72.0%).

In the adjusted regression models (Table 4), individuals under 12 years of age and those aged 13-17 years were significantly less likely to be injured by a firearm than individuals aged 18 to 24 years, regardless of the injury intent. Similarly, across all models, females were less likely to be injured by a firearm compared to males. The risk of unintentional and unspecified firearm injury was higher for non-powdered firearm injury (adjusted rate ratio 1.53 [95% CI 1.42, 1.64] and 2.20 [95% CI 1.73, 2.80], respectively). The risk of unintentional firearm injury was 8.34 times higher for non-powdered firearms compared to handguns in the unadjusted model and 14.75 times higher in the adjusted model. Similar, but not as strong, results were found for unspecified firearm injury. In the adjusted model, only small differences were observed in assaults by non-powdered firearms compared to handguns.

Discussion

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In this population-based study, we found that 5,486 children and youth up to 24 years of age between 2003 and 2017 were injured or killed by a firearm in Ontario, Canada. This is equivalent to a mean of 366 firearm injuries annually and a rate of firearm injuries of 8.7 per 100,000 population. Non-powdered firearms made up the largest proportion of firearm injuries overall, whereas rifles were responsible for almost twice the number of deaths as handguns when the weapon type was identified. Almost two thirds of all injuries were unintentional and almost one quarter were from an assault. Most injuries were to boys or young men and those living in either low income or urban neighbourhoods. Almost half of all injuries were to the head, thorax, or abdomen with only a minority causing superficial injuries. Our findings highlight the magnitude and characteristics of firearm injuries among youth in Ontario, Canada and these numbers suggest firearm injuries are a serious and potentially preventable public health problem.

This study underscores the significant variation in firearm injury rates by jurisdiction. In the United States, firearm injury rates among children are reported to be between 19 to 23.5 injuries per 100,000 individuals.[30,46] Prior to this work, little data are published on children and youth outside of the United States, making other cross-jurisdictional comparisons difficult.[1,13,30,47] Similar to American studies, we found males to be at greatest risk of firearm injuries, especially as they emerge into adulthood.[13,38] Also similar to American studies, where reported, we found that most injuries occurred at home. It has been well demonstrated that injury risk from all intents is highest where there are firearms in the household. This further emphasizes the importance of adherence to safe storage practices and supports child access prevention laws designed to reduce firearm injury.[48] Like others, we demonstrate children and youth living in low-income neighbourhoods experience the highest proportion of firearm injuries.[49,50] This finding was observed across all weapons and intents suggesting a need to improve community

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safety and target such communities for firearm safety, education, and enforcement of existing legislation.[30,49]

We showed that 1.9% of unintentional and 18.7% of assault-related firearm injuries are fatal with an overall fatality rate of 9.3%. This is consistent with other reported fatality rates in youth, ranging from 2 to 12%.[46,49,51,52] The high proportion of children and youth who do not die of their injuries highlights that firearm injury surveillance must include survivors, as reporting only deaths vastly underestimates the burden of the issue.[1] Further, most of these were open wounds and to the head and torso. These 'near misses' present an opportunity for action, including potential for mandatory eye and thoracic protection while using such weapons.

Among those with self-inflicted injuries, 72.0% died, demonstrating that in this context firearms are a highly lethal injury mechanism. We have previously reported 12% of suicide deaths in Ontario youth occur by firearm.[53] Eliminating access to firearms for those experiencing mental illness or distress may help to reduce both attempted and completed suicides by firearm.[54] There were 14.7% of self-inflicted firearm injuries from non-powdered firearms with risk of injury not different from those from handguns or rifles. This suggests access to non-powdered firearms must also be considered when counselling youth with mental health concerns at risk for intentional self-injury. In the current study, rifles were involved in 28.7% of self-inflicted injuries, a proportion almost identical to that described by Hanlon et al.[55]

A high number of unintentional injuries in this study were from non-powdered firearms. Young children under 12 years have a disproportionate risk of firearm injury by non-powdered firearms (73.8% of all firearm injuries) with a still important proportion affecting adolescents (59.6%) and emerging adults (32%). [56] Others have shown non-powdered firearms injuries cause morbidity,

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especially to the eyes[40], and depending on the mass of the bullet, can penetrate skin at 53 m/s.[41] Most prior studies on non-powdered firearms have been small, single centred, or limited to pediatric hospitals only.[42,57,58] However, one US study using a nationally representative sample showed children have 13,486 visits to emergency departments annually for non-powdered firearms.[58] Regulations and legislation around possession, acquisition, use and transport of non-powdered firearms vary considerably by jurisdiction. In the US, some jurisdictions have adopted laws to address safety concerns with some states defining non-powered firearms as firearms subject to the same or similar regulations.[56,58] In Canada, lower velocity (<152.4 metres per second) firearms do not fall under the Canada Firearms Act, nor are they regulated by the Consumer Protection and Safety Act. There is no mandatory training, supervision, or equipment required. Given the number of injuries associated with these weapons, increased regulation of non-powdered firearms, particularly for minors, may be warranted.

Understanding factors related to firearm injuries in varying jurisdictions is important for informing strategies for prevention. While the scale of the issue may be different, there may be opportunities to learn from leading jurisdictions in terms of successful injury prevention strategies. Diversity in firearm regulations and legislation and corresponding injury rates as seen in the United States, Australia, Canada and Japan, points to a need to consider adopting firearm injury prevention approaches used in jurisdictions with low rates of injury.[25-29,59]

Strengths and Limitations

This is the largest population-based study in Canada to examine the extent of firearm injuries in youth, with specific attention to weapon type. While data used have validated codes for intent and weapon type, we do not report data on perpetrators and have limited data on the

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circumstances surrounding the injury. Many firearm injuries were of undetermined intent and weapon type, highlighting the need for better firearm injury surveillance to be able to measure if strategies to reduce injury are effective. Further, because of there was a high degree of missingness for the weapon type, the proportional contribution of each weapon type may be over or underestimated. There is wide variation in firearm ownership and weapon type across Canada and rates of injury are likely higher in regions with greater firearm ownership. Our measures likely underestimate the true burden of injury, especially for milder injuries from non-powdered firearms that may not present to a hospital.

Conclusions

We report weapon type and intent of firearm injuries among youth in Ontario. Where the intent was known, approximately two-thirds were unintentional and likely preventable with appropriate and enforced firearm safety standards for youth. Firearm injuries with non-powdered firearms are concerningly high and assaults and self-injury contributed to substantial firearm-related deaths and must be a focus of ongoing injury prevention efforts and surveillance for youth.

For peer review only

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For peer review only

Table 1. Baseline characteristics of children and emerging adults (0 to 24 years) who experienced a firearm injury in Ontario, Canada, 2003 to 2017. All numbers n (%) unless otherwise specified.

Variable		Firearm injury survivor	Firearm deaths	Total injuries and deaths
Overall		4,976 (90.7)	510 (9.3)	5,486
Age, years				
	0 to 12	548 (11.0)	7 (1.4)	555 (10.1)
	13 to 17	1,464 (29.4)	92 (18.0)	1,556 (28.4)
	18 to 24	2,964 (59.6)	411 (80.6)	3,375 (61.5)
	Mean ± SD	17.9 ± 4.3	20.0 ± 3.0	18.1 ± 4.2
	Median (IQR)	19 (15-21)	20 (18-22)	19 (16-21)
Sex				
	Female	509 (10.2)	36 (7.1)	545 (9.9)
	Male	4,467 (89.8)	474 (92.9)	4,941 (90.1)
Neighbourhood income quintile				
	1 (low)	1,689 (33.9)	217 (42.5)	1,906 (34.7)
	2	1,069 (21.5)	114 (22.4)	1,183 (21.6)
	3	887 (17.8)	86 (16.9)	973 (17.7)
	4	774 (15.6)	57 (11.2)	831 (15.1)
	5 (high)	*520-524	*31-35	555 (10.1)
	Missing	*33-37	*1-5	38 (0.7)
Neighbourhood material deprivation quintile				
	1 (low)	546 (11.0)	33 (6.5)	579 (10.6)
	2	683 (13.7)	64 (12.5)	747 (13.6)
	3	863 (17.3)	71 (13.9)	934 (17.0)
	4	968 (19.5)	93 (18.2)	1,061 (19.3)
	5 (high)	1,755 (35.3)	236 (46.3)	1,991 (36.3)
	Missing	161 (3.2)	13 (2.5)	174 (3.2)
Rurality				
	Major urban centre	3,174 (63.8)	395 (77.5)	3,569 (65.1)
	Urban	1,141 (22.9)	54 (10.6)	1,195 (21.8)
	Rural	505 (10.1)	45 (8.8)	550 (10.0)
	Missing	156 (3.1)	16 (3.1)	172 (3.1)
Immigrant status				
	Non-refugee immigrants	387 (7.8)	64 (12.5)	451 (8.2)
	Non-immigrants	4,380 (88.0)	418 (82.0)	4,798 (87.5)
	Refugee immigrants	209 (4.2)	28 (5.5)	237 (4.3)
Hospital type at presentation				
	Community	3,162 (63.5)	55 (10.8)	3,217 (58.6)
	Pediatric	*232-236	*1-5	237 (4.3)
	Teaching	*1578-1582	*130-134	1,712 (31.2)
	None	0 (0.0)	320 (62.7)	320 (5.8)
Firearm type				
	Handgun	343 (6.9)	*39-43	383 (7.0)
	Rifle	269 (5.4)	69 (13.5)	338 (6.2)
	BB guns/non-powdered firearm	*2412-2416	*1-5	2,417 (44.1)
	Unspecified firearm	1,907 (38.3)	380 (74.5)	2,287 (41.7)
Injury intent				
	Unintentional	3,351 (67.3)	65 (12.7)	3,416 (62.3)
	Assault	1,180 (23.7)	272 (53.3)	1,452 (26.5)
	Self-harm	57 (1.1)	147 (28.8)	204 (3.7)
	Undetermined	347 (7.0)	6 (1.2)	353 (6.4)
	Legal intervention	41 (0.8)	20 (3.9)	61 (1.1)

*Small cell sizes (<6) have been suppressed and combined with largest group to prevent back calculation as per institutional policy.

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Table 2. Characteristics of firearm injury for children and emerging adults (0 to 24 years) in Ontario, Canada, 2003 to 2017. All numbers n (%).

				Weapon Type				
	Firearm injury survivor	Firearm deaths	Total injuries and deaths	Handguns	Rifles	BB guns or non-powdered firearm	Legal	Other or Unspecified
Place of injury								
Home	476 (9.6)	31 (6.1)	507 (9.2)	* 42 - 46	46 (13.6)	246 (10.2)	*1 - 5	168 (7.3)
School	*30-34	*1-5	35 (0.6)	*1 - 5	*1 - 5	9 (0.4)	0 (0.0)	19 (0.8)
Athletic facility	*22-26	*1-5	27 (0.5)	*1 - 5	*1 - 5	*1 - 5	0 (0.0)	18 (0.8)
Street	275 (5.5)	23 (4.5)	298 (5.4)	44 (11.5)	* 13 - 17	53 (2.2)	*1 - 5	183 (8.0)
Trade	*133-137	*1-5	138 (2.5)	* 15 - 19	*1 - 5	26 (1.1)	0 (0.0)	92 (4.0)
Farm	12 (0.2)	0 (0.0)	12 (0.2)	0 (0.0)	*1 - 5	7 (0.3)	0 (0.0)	*1 - 5
Other/not specified	4,073 (81.9)	121 (23.7)	4,194 (76.4)	282 (73.6)	220 (65.1)	2,103 (87.0)	19 (31.1)	1,570 (68.6)
Nature of injury								
Fracture	685 (13.8)	27 (5.3)	712 (13.0)	121 (31.6)	73 (21.6)	45 (1.9)	13 (21.3)	460 (20.1)
Internal organ injury	434 (8.7)	76 (14.9)	510 (9.3)	97 (25.3)	44 (13.0)	10 (0.4)	17 (27.9)	342 (15.0)
Open wound	3,300 (66.3)	215 (42.2)	3,515 (64.1)	262 (68.4)	194 (57.4)	1,559 (64.5)	36 (59.0)	1,464 (64.0)
Amputation	16 (0.3)	0 (0.0)	16 (0.3)	*1 - 5	*1 - 5	*1 - 5	0 (0.0)	8 (0.3)
Blood vessel	114 (2.3)	19 (3.7)	133 (2.4)	26 (6.8)	11 (3.3)	*1 - 5	*1 - 5	90 (3.9)
Superficial contusion	*689-693	*1-5	694 (12.7)	19 (5.0)	20 (5.9)	494 (20.4)	6 (9.8)	155 (6.8)
Effect of foreign bodies entering orifice	72 (1.4)	0 (0.0)	72 (1.3)	0 (0.0)	*5 - 9	50 (2.1)	*1 - 5	13 (0.6)
Other specified	400 (8.1)	21 (4.1)	421 (7.7)	51 (13.3)	35 (10.3)	116 (4.8)	12 (19.7)	209 (9.1)
Unspecified	370 (7.4)	4 (0.8)	374 (6.8)	8 (2.1)	9 (2.7)	240 (9.9)	0 (0.0)	117 (5.1)
Type of injury								
Traumatic brain	849 (17.1)	107 (21.0)	956 (17.4)	* 66 - 70	85 (25.1)	512 (21.2)	*1 - 5	288 (12.6)
Head (no brain)	883 (17.7)	6 (1.2)	889 (16.2)	* 20 - 24	34 (10.1)	645 (26.6)	*1 - 5	185 (8.1)
Neck	155 (3.1)	22 (4.3)	177 (3.2)	18 (4.7)	* 8 - 12	58 (2.4)	*1 - 5	88 (3.8)
Thorax	384 (7.7)	105 (20.6)	489 (8.9)	62 (16.2)	29 (8.6)	64 (2.6)	20 (32.8)	314 (13.7)
Vertebral column/Spine	119 (2.4)	12 (2.4)	131 (2.4)	28 (7.3)	*7 - 11	*1-5	*1 - 5	87 (3.8)
Abdomen, lower back, pelvis	826 (16.4)	86 (16.9)	912 (16.7)	146 (38.1)	59 (17.4)	74 (3.0)	27 (44.2)	606 (26.5)
Upper extremity	1,504 (30.2)	27 (5.3)	1,531 (27.9)	125 (32.6)	81 (24.0)	749 (31.0)	18 (29.5)	558 (24.4)
Lower extremity	1,238 (24.9)	18 (3.5)	1,256 (22.9)	126 (32.9)	74 (21.9)	363 (15.0)	13 (21.3)	680 (29.7)
Multiple/system wide region	102 (2.0)	23 (4.5)	125 (2.3)	18 (4.7)	14 (4.2)	*8-16	*1 - 5	76 (3.3)
Unspecified region	*50-54	*1-5	55 (1.0)	*1 - 5	0 (0.0)	11 (0.5)	*1 - 5	42 (1.8)

*Small cell sizes (<6) have been suppressed and combined with largest group to prevent back calculation as per institutional policy.

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Table 3. Firearm injuries among children and emerging adults (0 to 24 years) in Ontario, Canada, 2003 to 2018 by weapon type and intent. All numbers n, (rate per 100,000 population).

	Overall	Age, years			Sex		Income Quintile		Rurality		
	total	0-12	13-17	18-24	Female	Male	Lowest	Highest	Major Urban	Urban	Rural
Overall											
Handgun	383 (0.61)	6 (0.02)	59 (0.44)	318 (1.63)	32 (0.11)	351 (1.10)	193 (1.56)	24 (0.19)	351 (0.77)	19 (0.16)	11 (0.26)
Rifle	338 (0.54)	22 (0.07)	80 (0.60)	236 (1.21)	42 (0.14)	296 (0.93)	97 (0.78)	41 (0.32)	187 (0.41)	77 (0.64)	52 (1.22)
BB gun	2,417 (3.88)	410 (1.40)	927 (6.91)	1,080 (5.53)	257 (0.85)	2,160 (6.76)	628 (5.08)	337 (2.64)	1,129 (2.49)	825 (6.90)	359 (8.44)
Unspecified	2,287 (3.67)	116 (0.39)	480 (3.58)	1,691 (8.66)	214 (0.70)	2,073 (6.49)	970 (7.85)	150 (1.17)	1,861 (4.11)	260 (2.18)	125 (2.94)
Firearm Injuries by Intent											
Unintentional											
Handgun	96 (0.15)	-	23 (0.14)	73 (0.37)	17 (0.06)	79 (0.25)	41 (0.33)	8 (0.06)	79 (0.17)	11 (0.09)	6 (0.14)
Rifle	161 (0.26)	15 (0.05)	41 (0.31)	105 (0.54)	28 (0.09)	133 (0.42)	45 (0.36)	26 (0.20)	70 (0.15)	49 (0.41)	30 (0.71)
BB gun	1,913 (3.07)	340 (1.16)	767 (5.72)	806 (4.13)	192 (0.63)	1,721 (5.39)	479 (3.88)	273 (2.14)	841 (1.86)	683 (5.71)	304 (7.15)
Unspecified	1,246 (2.00)	98 (0.33)	281 (2.10)	867 (4.44)	125 (0.41)	1,121 (3.51)	503 (4.07)	96 (0.75)	947 (2.09)	190 (1.59)	85 (2.00)
Assault											
Handgun	265 (0.43)	-	36 (0.25)	229 (1.17)	13 (0.04)	252 (0.79)	143 (1.16)	12 (0.09)	257 (0.56)	6 (0.05)	-
Rifle	94 (0.15)	-	14 (0.09)	80 (0.41)	-	94 (0.28)	36 (0.29)	-	83 (0.18)	8 (0.07)	-
BB gun	246 (0.39)	38 (0.13)	81 (0.60)	127 (0.65)	41 (0.13)	205 (0.64)	73 (0.59)	27 (0.21)	151 (0.33)	64 (0.54)	20 (0.47)
Unspecified	847 (1.3)	9 (0.03)	151 (1.13)	687 (3.52)	67 (0.22)	780 (2.44)	410 (3.32)	37 (0.29)	811 (1.78)	29 (0.24)	-
Self-harm											
Handgun	13 (0.02)	-	-	13 (0.05)	-	13 (0.04)	-	-	13 (0.02)	-	-
Rifle	59 (0.09)	-	19 (0.13)	40 (0.20)	-	59 (0.17)	12 (0.10)	8 (0.06)	26 (0.06)	15 (0.13)	13 (0.31)
BB gun	30 (0.05)	-	11 (0.05)	19 (0.10)	-	30 (0.09)	9 (0.07)	-	15 (0.03)	14 (0.11)	-
Unspecified	102 (0.16)	-	22 (0.16)	80 (0.41)	11 (0.04)	91 (0.28)	23 (0.19)	10 (0.08)	43 (0.09)	28 (0.23)	25 (0.59)
Undetermined											
Handgun	9 (0.01)	-	-	9 (0.04)	-	9 (0.03)	7 (0.06)	-	9 (0.02)	-	-
Rifle	24 (0.04)	-	13 (0.07)	11 (0.06)	-	24 (0.06)	-	-	15 (0.02)		7 (0.16)
BB gun	228 (0.37)	28 (0.10)	72 (0.54)	128 (0.66)	22 (0.07)	206 (0.64)	67 (0.54)	33 (0.26)	122 (0.27)	65 (0.54)	34 (0.80)
Unspecified	92 (0.15)	9 (0.03)	26 (0.19)	57 (0.29)	11 (0.04)	81 (0.25)	34 (0.28)	7 (0.05)	65 (0.14)	13 (0.11)	10 (0.24)

*Small cell sizes (<6) have been suppressed and combined with largest group in row to prevent back calculation as per institutional policy.
Legal intervention not included due to small cell sizes.

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Table 4. Rate ratios of firearm injuries by intent for children and emerging adults (0 to 24 years) in Ontario, Canada, 2003 to 2018.

Variable	Model 1				Model 2			
	Unintentional injuries	Assault-related injuries	Self-harm injuries	Unspecified injuries	Unintentional injuries	Assault-related injuries	Self-harm injuries	Unspecified injuries
	RR ($CI_{95\%}$)	RR ($CI_{95\%}$)	RR ($CI_{95\%}$)	RR ($CI_{95\%}$)	RR ($CI_{95\%}$)	RR ($CI_{95\%}$)	RR ($CI_{95\%}$)	RR ($CI_{95\%}$)
Weapon Type								
Handgun	0.17 (0.14-0.21)	0.51 (0.44-0.58)	0.47 (0.26-0.83)	0.56 (0.28-1.14)	0.10 (0.08-0.13)	0.34 (0.30-0.40)	0.40 (0.22-0.71)	0.39 (0.19-0.77)
Rifle	0.19 (0.16-0.22)	0.24 (0.19-0.29)	0.63 (0.45-0.87)	0.55 (0.35-0.87)	0.15 (0.13-0.75)	0.14 (0.11-0.17)	0.58 (0.42-0.80)	0.53 (0.34-0.84)
BB gun	1.42 (1.32-1.52)	0.26 (0.23-0.30)	0.39 (0.26-0.58)	1.85 (1.45-2.36)	1.53 (1.42-1.64)	0.29 (0.25-0.33)	0.41 (0.26-0.61)	2.20 (1.73-2.81)
Unspecified (ref)	1.00	---	---	---	--	--	--	--
Age								
0-12					0.18 (0.16-0.20)	0.08 (0.06-0.11)	0.34 (0.14-0.87)	0.21 (0.15-0.29)
13-17					0.88 (0.82-0.95)	0.39 (0.34-0.44)	0.83 (0.61-1.15)	0.89 (0.71-1.13)
18-24 (ref)					1.00	--	--	--
Sex								
Female					0.14 (0.12-0.15)	0.14 (0.11-0.17)	0.37 (0.22-0.60)	0.39 (0.28-0.54)
Male (ref)					1.00	--	--	--
Contrasts								
Rifles vs Handgun	1.12 (0.87-1.45)	0.47 (0.37-0.59)	1.34 (0.74-2.44)	0.98 (0.46-2.12)	1.43 (1.11-1.84)	0.40 (0.32-0.50)	1.47 (0.80-2.68)	1.38 (0.64-2.97)
BB guns vs Handgun	8.34 (6.79-10.23)	0.52 (0.44-0.62)	0.83 (0.43-1.58)	3.29 (1.69-6.41)	14.75 (12.01-18.12)	0.84 (0.70-1.00)	1.01 (0.52-1.95)	5.68 (2.90-11.11)
Unspecified vs Handgun	5.88 (4.78-7.24)	1.98 (1.72-2.27)	2.14 (1.20-3.81)	1.78 (0.90-3.53)	9.65 (7.84-11.88)	2.90(2.53-3.33)	2.52 (1.41-4.50)	2.58 (1.30-5.13)

Note. CI = confidence interval; Ref = reference category; RR = rate ratio; Model 1 includes firearm type only. Model 2 adds in covariates (i.e., age and sex).

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APPENDIX

FIREARM INJURIES

W32: Handgun discharge
W33: Rifle, shotgun and larger firearm discharge
W3400: Discharge from BB gun
W3401: Discharge from air gun
W3408: Discharge from other specified firearms
W3409: Discharge from unspecified firearm

X93: Assault by handgun discharge
X94: Assault by rifle, shotgun & larger firearm discharge
X9500: Assault by BB gun discharge
X9501: Assault by air gun discharge
X9508: Assault by other specified firearm discharge
X9509: Assault by unspecified firearm discharge

X72: Intentional self-harm by handgun discharge
X73: Intentional self-harm by rifle, shotgun & larger firearm discharge
X7400: Intentional self-harm BB gun discharge
X7401: Intentional self-harm air gun discharge
X7408: Intentional self-harm other specified firearm discharge
X7409: Intentional self-harm by unspecified firearm discharge

Y22: Handgun discharge undetermined intent
Y23: Rifle shotgun & larger firearm discharge undetermined intent
Y2400: BB gun discharge, undetermined intent
Y2401: Air gun discharge, undetermined intent
Y2408: Other specified firearm discharge, undetermined intent
Y2409: Unspecified firearm discharge, undetermined intent

Y35.0 - Legal intervention involving firearm discharge

INTENT

Unintentional Firearm Injury (ORGD only use the first 3 digits W32, W33, W34)
W32: Handgun discharge
W33: Rifle, shotgun and larger firearm discharge
W3400: Discharge from BB gun
W3401: Discharge from air gun
W3408: Discharge from other specified firearms
W3409: Discharge from unspecified firearm

Assault from firearm (intentional), ORGD only use the first 3 digits X93, X94, X95
X93: Assault by handgun discharge
X94: Assault by rifle, shotgun & larger firearm discharge
X9500: Assault by BB gun discharge
X9501: Assault by air gun discharge

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X9508: Assault by other specified firearm discharge
X9509: Assault by unspecified firearm discharge

Self-harm from firearm (suicide) ORGD only use the first 3 digits X72, X73, X74
X72: Intentional self-harm by handgun discharge
X73: Intentional self-harm by rifle, shotgun & larger firearm discharge
X7400: Intentional self-harm BB gun discharge
X7401: Intentional self-harm air gun discharge
X7408: Intentional self-harm other specified firearm discharge
X7409: Intentional self-harm by unspecified firearm discharge

Intent unknown (undetermined) ORGD only use the first 3 digits Y22, Y23, Y24
Y22: Handgun discharge undetermined intent
Y23: Rifle shotgun & larger firearm discharge undetermined intent
Y2400: BB gun discharge, undetermined intent
Y2401: Air gun discharge, undetermined intent
Y2408: Other specified firearm discharge, undetermined intent
Y2409: Unspecified firearm discharge, undetermined intent

Legal Interventions
Y35.0 - Legal intervention involving firearm discharge

If there were multiple intents in one injury episode, the following rules were used to decide the intent
Assault*intent unknown = assault
Assault*legal intervention = assault
Self-harm*intent unknown = self-harm
Unintentional*assault = assault
Unintentional*assault*legal intervention = assault
Unintentional*intent unknown = unintentional
Unintentional*legal intervention = unintentional
Unintentional*self-harm = self-harm.

WEAPON TYPE
Handgun
W32: Handgun discharge
X93: Assault by handgun discharge
X72: Intentional self-harm by handgun discharge
Y22: Handgun discharge undetermined intent

Rifle
W33: Rifle, shotgun and larger firearm discharge
X94: Assault by rifle, shotgun & larger firearm discharge
X73: Intentional self-harm by rifle, shotgun & larger firearm discharge
Y23: Rifle shotgun & larger firearm discharge undetermined intent

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BB Guns and Airgun
W3400: Discharge from BB gun
W3401: Discharge from air gun
X9500: Assault by BB gun discharge
X9501: Assault by air gun discharge
X7400: Intentional self-harm BB gun discharge
X7401: Intentional self-harm air gun discharge
Y2400: BB gun discharge, undetermined intent
Y2401: Air gun discharge, undetermined intent

Other and Unspecified
W3408: Discharge from other specified firearms
W3409: Discharge from unspecified firearm
X9508: Assault by other specified firearm discharge
X9509: Assault by unspecified firearm discharge
X7408: Intentional self-harm other specified firearm discharge
X7409: Intentional self-harm by unspecified firearm discharge
Y2408: Other specified firearm discharge, undetermined intent
Y2409: Unspecified firearm discharge, undetermined intent

Multiple weapons, the following rules apply:
BB*other = BB
Handgun*BB = First use hospitalization record, then use handgun
Handgun*other = Handgun
Handgun*rifle = First use hospitalization and then use handgun
Rifle*BB and Rifle*other = Rifle.

PLACE OF INJURY OCCURRENCE

Home or residential institution: U980, U981
School, other institution/public area: U982, U9820, U9828
Athletic areas: U983
Street/highway: U984
Trade/service/industrial/construction area: U985, U986
Farm: U987
Other/unspecified: U988, U989

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DATA SOURCES AND ASSOCIATED STUDY VARIABLES

Data source	Variables	Linkage rates (for April 2003 – March 2018)
Registered Person Database (RPDB)	Patient sex, residential postal code, date of birth	
Immigration, Refugees and Citizenship Canada's Permanent Resident Database	Immigration status	74.0% - 90.9%
Ontario Registrar General – Deaths	Death	98.0% - 100.0%
National Ambulatory Care Reporting System	Emergency department visits, diagnoses	97.2% - 97.8%
Canadian Institutes for Health Information Discharge Abstract Database	Hospitalizations, diagnoses	97.6% - 98.0%
Ontario Marginalization Index	Material deprivation quintile	
2016 Canadian Census	Rurality	

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The RECORD statement – checklist of items, extended from the STROBE statement, that should be reported in observational studies using routinely collected health data.

	Item No.	STROBE items	Location in manuscript where items are reported	RECORD items	Location in manuscript where items are reported
Title and abstract					
	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 1, 4	RECORD 1.1: The type of data used should be specified in the title or abstract. When possible, the name of the databases used should be included. RECORD 1.2: If applicable, the geographic region and timeframe within which the study took place should be reported in the title or abstract. RECORD 1.3: If linkage between databases was conducted for the study, this should be clearly stated in the title or abstract.	Page 4
Introduction					
Background rationale	2	Explain the scientific background and rationale for the investigation being reported	Page 5		
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 6		
Methods					
Study Design	4	Present key elements of study design early in the paper	Page 7		
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 7		

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Participants	6	*(a) Cohort study* - Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study* - Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study* - Give the eligibility criteria, and the sources and methods of selection of participants *(b) Cohort study* - For matched studies, give matching criteria and number of exposed and unexposed *Case-control study* - For matched studies, give matching criteria and the number of controls per case	Page 8	RECORD 6.1: The methods of study population selection (such as codes or algorithms used to identify subjects) should be listed in detail. If this is not possible, an explanation should be provided. RECORD 6.2: Any validation studies of the codes or algorithms used to select the population should be referenced. If validation was conducted for this study and not published elsewhere, detailed methods and results should be provided. RECORD 6.3: If the study involved linkage of databases, consider use of a flow diagram or other graphical display to demonstrate the data linkage process, including the number of individuals with linked data at each stage.	Page 8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable.	Page 8, 9	RECORD 7.1: A complete list of codes and algorithms used to classify exposures, outcomes, confounders, and effect modifiers should be provided. If these cannot be reported, an explanation should be provided.	Page 8, 9, Appendix
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Page 8, 9		

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Bias	9	Describe any efforts to address potential sources of bias	Page 9		
Study size	10	Explain how the study size was arrived at	Page 8		
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	Page 8, 9		
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) *Cohort study* - If applicable, explain how loss to follow-up was addressed *Case-control study* - If applicable, explain how matching of cases and controls was addressed *Cross-sectional study* - If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses	Page 9		
Data access and cleaning methods		..		RECORD 12.1: Authors should describe the extent to which the investigators had access to the database population used to create the study population.	Page 3

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				RECORD 12.2: Authors should provide information on the data cleaning methods used in the study.	
Linkage		..		RECORD 12.3: State whether the study included person-level, institutional-level, or other data linkage across two or more databases. The methods of linkage and methods of linkage quality evaluation should be provided.	Page 8
Results					
Participants	13	(a) Report the numbers of individuals at each stage of the study (*e.g.*, numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed) (b) Give reasons for non-participation at each stage. (c) Consider use of a flow diagram	Page 10	RECORD 13.1: Describe in detail the selection of the persons included in the study (*i.e.,* study population selection) including filtering based on data quality, data availability and linkage. The selection of included persons can be described in the text and/or by means of the study flow diagram.	Page 10
Descriptive data	14	(a) Give characteristics of study participants (*e.g.*, demographic, clinical, social) and information on exposures and potential confounders (b) Indicate the number of participants with missing data for each variable of interest (c) *Cohort study* - summarise follow-up time (*e.g.*, average and total amount)	Page 10		
Outcome data	15	*Cohort study* - Report numbers of outcome events or summary measures over time *Case-control study* - Report numbers in each exposure	Page 10		

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		category, or summary measures of exposure *Cross-sectional study* - Report numbers of outcome events or summary measures			
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Page 10, 11		
Other analyses	17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	NA		
Discussion					
Key results	18	Summarise key results with reference to study objectives	Page 11		
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Page 12	RECORD 19.1: Discuss the implications of using data that were not created or collected to answer the specific research question(s). Include discussion of misclassification bias, unmeasured confounding, missing data, and changing eligibility over time, as they pertain to the study being reported.	Page 12
Interpretation	20	Give a cautious overall interpretation of results considering objectives,	Page 11, 12		

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		limitations, multiplicity of analyses, results from similar studies, and other relevant evidence			
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 12		
Other Information					
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 2		
Accessibility of protocol, raw data, and programming code		..		RECORD 22.1: Authors should provide information on how to access any supplemental information such as the study protocol, raw data, or programming code.	Page 3

*Reference: Benchimol EI, Smeeth L, Guttmann A, Harron K, Moher D, Petersen I, Sørensen HT, von Elm E, Langan SM, the RECORD Working Committee. The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) Statement. *PLoS Medicine* 2015; in press.

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